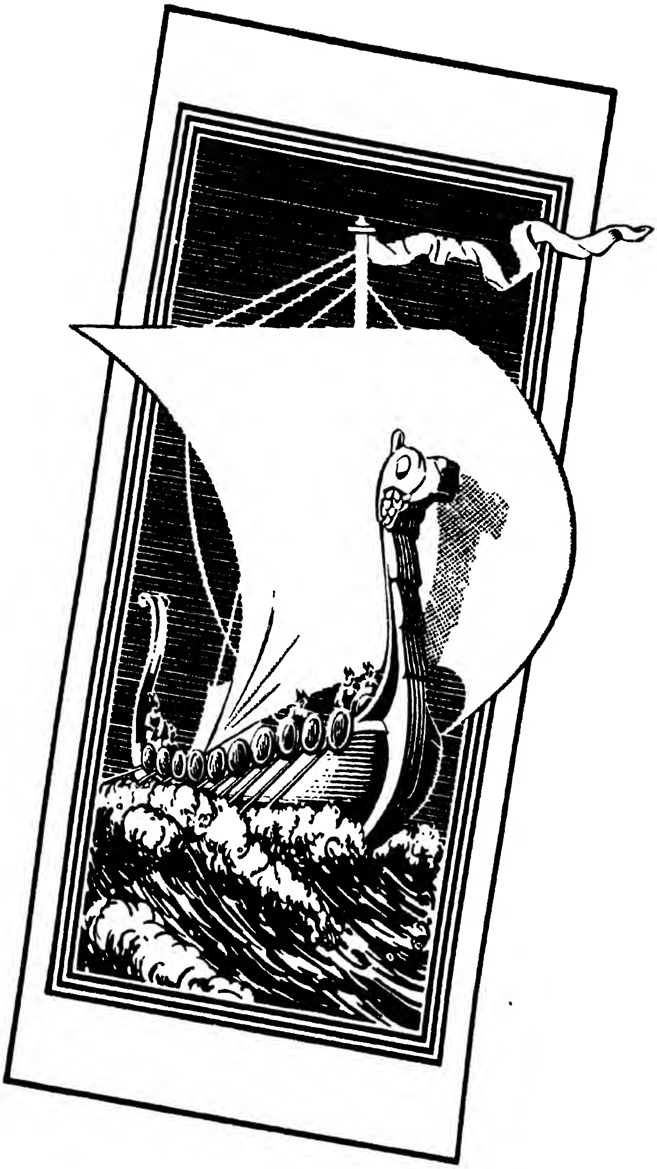

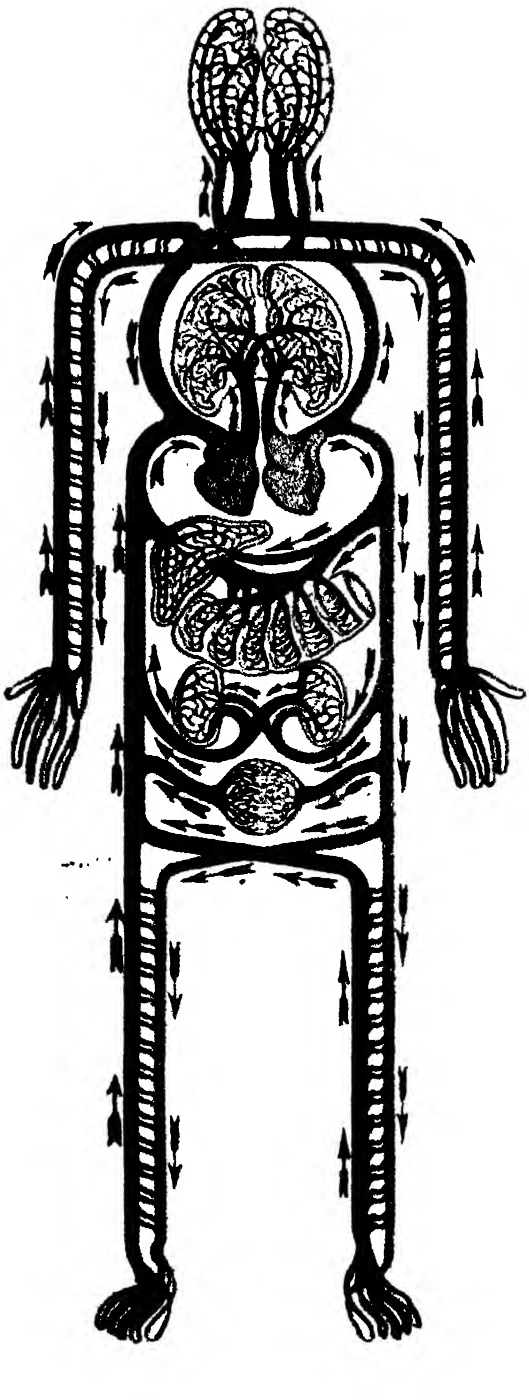

In this diagram the arrows show the course of the circulating blood. Arterial blood is red, venous blue. Suppose we start at the left ventricle, the lower heart cavity, shown in any picture on the right side. Then the arrows guide us to the arteries—capillaries—veins—right auricle—right ventricle—pulmonary artery—lungs—pulmonary vein—left auricle—and so back to the point where we started.

Richards Topical Encyclopedia

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CONTENTS

VOLUME II

THE STORY OF PLANT LIFE

(Botany)

(For specific facts relating to this subject consult the Index)

The story of plant life has been presented in such a way that the reader who follows the units in the order of their presentation may more easily understand and remember the subject

WONDERS OF THE HUMAN BODY

(*Physiology*)

(*For specific facts relating to this subject consult the Index*)

CONSERVING HUMAN LIFE

(*For specific facts relating to this subject consult the Index*)

COLOR PLATES

KEY TO PRONUNCIATION

ā, as in māte
ȧ, as in senȧte
â, as in hâir
ă, as in hăt
ä, as in fäther
a, a sound between ä and ă, as in càstle
ch, as in chest
ē, as in ēve
ė, as in rėlate
ĕ, as in bĕnd
ẽ, as in readẽr
g, as in go
ī, as in bīte
ĭ, as in ĭnn
k, as in key
K, the guttural sound of ch, as in the German *ach*, or the Scotch *loch*
n, as in not
N, the French nasal sound, as in *bon*
ng, the English nasal sound, as in strong
ō, as in bōne
ŏ, as in Christŏpher
ô, as in lôrd
ŏ, as in hŏt
oi, as in toil
o͞o, as in so͞on
o͝o, as in bo͝ok
ou, as in shout
s, as in so
sh, as in ship
th, as in thumb
t͟h, as in t͟hus
ū, as in cūre
u̇, as in accu̇rate
û, as in fûr
ŭ, as in ŭs
ü, a sound formed by pronouncing ē with the lips in the position for o͞o, as in the German *über* and the French *une*
zh, as in azure
', an indication that a vowel sound occurs, but that it is elided and cannot be identified, as in apple (ăp''l)
A heavy accent (′) follows a syllable receiving the principal stress, and a lighter accent (') follows a syllable receiving a secondary stress.

Photo by Nevada State Highway Department

Protected by woody stem and bristling spines the Joshua tree rears its greenish-white lilies across the deserts of Mexico and the Southwestern United States. It often reaches a height of thirty feet.

Reading Unit No. 1

WHAT IS BOTANY?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What "botany" means, 2–1
How all living things depend on plants, 2–1
The uses of plants, 2–1-2
The work of botanists, 2–2-4

Things to Think About

What was man's interest in plants formerly based on?
How much of our food, medicines, fuel, and furniture comes from plants?
Why do people study plants to-day?
Is there any paid work in the world to-day for people who wish to study plants?

Picture Hunt

What kind of plants lived on the earth before man? 2–1
What kind of plants made coal? 2–2
How do we know that part of the United States was once covered by an ocean? 2–2

Related Material

What part did Linnaeus play in teaching us how to classify plants? 13–410-11
How are plants named? 2–182-85
Why was every English ship once required to carry lemons on every voyage? 9–175
What is the value of our annual corn crop? 9–106

Leisure-time Activities

PROJECT NO. 1: If you live near a coal mine, visit the dump pile and look for fossils in coal, 2–2.

PROJECT NO. 2: Devote a plot in your garden to plants from which drugs are made, 2–3.

PROJECT NO. 3: To understand the need for classification, collect a wide variety of leaves and try to arrange them, 2–3.

Summary Statement

Mankind has always depended upon plants. Plants are so important to the life of man that many scientists spend their lives in discovering, classifying, and understanding plant life.

Photo by Field Museum

This is the way one artist pictures a plant community of many ages ago, before men appeared on earth. The treelike plants are not trees at all, but giant ferns. The smaller ones are horsetails and club mosses or ground pine. None of the green things most familiar to-day had yet appeared. We know something of the plants of those old forests because we have found their fossil remains in the rocks.

WHAT IS BOTANY?

How Long Have Men Been Exploring Its Secrets, and in What Different Ways Do They Affect Us?

WHEN the first men began roaming about the world, there were plenty of plants around them but there was no such science as botany. For botany is a systematized knowledge of plants, and it was some time before men began to arrange that knowledge. Even then, for thousands of years, their thoughts about the subject were all fairly simple. "What is this plant good for? Will its wood make good boats? Is its fruit good to eat or is it poisonous? Will its juice cure fever?" That was the kind of question men asked.

For a long time they studied the plants only to see which of them could be used or eaten. That study is still going on, for without plants no animals could exist. A large part of our food, including such things as fruits, vegetables, flour, cereals, and sugar, comes directly from plants. All of our food comes eventually from plants; for the milk, eggs, fish, and meat that we eat were produced by animals which got their food directly or indirectly from plants. Most of the medicines that our doctors use come from plants. Most of the materials we use for clothing and for making many useful things also come directly or indirectly from plants or are made from plant products. A large part of the materials from which we get heat and power were also first made by plants. These are wood, coal, peat, oil, gasoline, and gas. Because we eat and use so much that comes from plants, thousands of people, all the way from small farmers to especially trained scientists, spend their lives

in studying and growing plants, in finding new uses for them or in finding better ways of growing them. This kind of study is called "economic botany," because it tells us of the uses of plants.

In addition to the use of plant material by very primitive people for food, clothing, shelter, tools or weapons, and fuel, people from ancient times to the present have also used plant material as medicines for curing their various ailments. In fact, our oldest writings and books on plants deal largely with their use in medicine, and the earliest botanical gardens were chiefly collections of medicinal plants. It is true that the curative properties ascribed to some of these plants were as false as the claims for many patent medicines to-day, but many of the plants used by the medical men of ancient times are still used to our time. That field of botany which deals with medicinal plants is often known as "pharmaceutical (fär'mȧ-sū'tĭ-kăl) botany."

Photo by U. S. Biological Survey

Here is one of the very fern leaves of some prehistoric forest such as that pictured on the preceding page. It has been kept for us all these ages in a lump of coal.

The day came, however, when men were no longer thinking solely about the food or drugs or medicines they could get from plants, and they began to ask other questions. Why are there so many kinds of plants? Are they related to one another? Why do some plants grow in water, others on land, some in dry deserts and others in swamps? Why do some grow only in hot regions and others only on cold mountain tops or near the Arctic regions? Does a plant need food as we do and where does it get its food? What makes some plants sicken and die, and how can they be kept healthy? Long ago men started asking a good many questions like these. When the old Greeks began asking such questions about plants they were thinking not so much about what a plant is good for as about what it really *is*. Theophrastus (thē'ō-frăs'tŭs), one of the most learned of the Greeks, asked thousands of these questions and tried to answer some of them. Of course he could never answer all of them, any more than we can answer them all to-day, though it is two thousand years since he used to walk about his garden wondering why plants did this and that.

Trying to answer the questions of Theophrastus and of other people who have followed him has kept many men busy all their lives. And yet the answers to a mere set of random questions would not quite make up what we call botany. Random questions and random answers do not make a science, and botany is the science of plant life. Theophrastus found that haphazard questions did not get him very far, and that it was much better to put the questions and the answers into some sort of plan. The old Greek soon began sorting his questions and answers in order to be able to find them; and we have gone on doing the same thing ever since. We have now done it for so long, and so many books have been written about it, that we know far more than the Greeks. Indeed, botany has grown to be so large a science that no one man can hope to know it all. What we can do here is to stop asking random questions

The great, hard spiral below is thought to be the fossilized stem of a sea plant called Daemonelix. It was found in Nebraska, a part of our country that we know was once covered by the ocean.

Photo by Field Museum

Photo by American Red Cross

Even wild plants, to which many people pay little attention, often have unexpected uses. These two boys are picking milkweed pods, which have been found to be a good substitute for kapok in stuffing cushions and such.

and see what has come of sorting all the questions in the past.

What is this plant? Does it grow for only one year, like so many weeds and garden herbs and flowers, or for several years, like the garden rose, or for a great many years, like the oak tree? With these questions we begin sorting plants, just as we might sort marbles, by an easy method which gives us the first simple division of all plants into herbs, shrubs, and trees. Theophrastus, who started all this, knew as well as we do that the herbs are not all alike, that a rose bush is not the same as a lilac, and that oak trees and pines are very different. But what are all the differences? For two thousand years we have been noting all these differences, big and little, and trying to make certain classes of the plants under a scientific system. That is the work of "systematic botany," which takes up all the questions and answers about the kinds and relationships of plants, how one kind of plant is like other kinds, and how it is different from them, whether it bears flowers or not, what kind of flowers and fruits it bears, whether it is evergreen or not, whether it grows on land or water, whether it has simple leaves or compound leaves or no leaves at all, and many another question.

How to Know the Plants Apart

Perhaps you may be thinking that every one can tell an oak from a pine tree, and wondering why we need a system at all. But could you tell a red pine from a white pine? If so, how would you do it? Only in the way that everyone has used, from the days of Theophrastus down—by comparing the leaves or cones or bark, or other features of the trees. And there are so many features to notice in plants that we have books full of their differences. For most plants have roots, stems, leaves, flowers, fruits, and seeds, and all these various organs are as different as the heads and feet and hair or fur of different animals. That kind of botany which is taken up with these differences and the sorting of them into classes is what we know as "morphological (môr′fô-lŏj′ĭ-kăl) botany,"

or the study of plant structures and plant organs.

Then there are questions about the activities of plants: why they grow rapidly under some conditions and slowly under others; how a plant gets its food; what fertilizers are necessary for plants and why; what effects light has upon plants, and whether all plants need light; why some plants take up so much water; why so few plants grow in a desert; what makes some seeds lie dormant in the soil for years before they germinate. These are questions about what plants do; and studies of what plants do form another division of botany, usually called "physiological botany" or "plant physiology." To learn what is happening inside plants, what the different organs and parts are doing, makes an attractive story and a very interesting subject of study.

There is another part of botany which is often considered a branch of physiology but which is called "plant ecology" (ē-kŏl′ō-jĭ). In this field of botany more attention is given to the relations between plants and their natural environment, and students try to find out why certain kinds of plants are often restricted to particular regions. In these studies men are trying to answer such questions as why we find such different kinds of plants in different regions—in prairies and wooded ravines, for instance, or in swamps and deserts, on mountain tops and in tropical forests. To what extent and why do the moisture, the light, temperature, and soil conditions influence the natural distribution of vegetation? And what effects do other plants and animals have upon this distribution? You would be surprised to find a cactus in a wooded ravine or a maidenhair fern in a desert, a banana or coconut in Arctic regions or on high mountain tops, and a spruce in a tropical forest. Studies of these relations of plants to their environment, of how and why they are well suited to the places in which they grow and are not well fitted to live in other places, are called studies in plant ecology.

As we said in the beginning, botany is the name given to systematized knowledge about plants. This knowledge has now become so extensive that it is impossible for a single individual to be thoroughly acquainted with all that is known about plants. The subject has therefore been subdivided into many divisions and men have become specialists as investigators, as teachers, and as workers in the different fields of botany. There is that field of botany which is concerned with the uses of plants—economic botany; with the different kinds of plants—systematic botany; with the doings of plants—physiological botany; with the relations of plants to their environment—ecological botany—with the diseases of plants—plant pathology (pă-thŏl′ō-jĭ); with the development of new varieties of plants—plant breeding; with plants invisible to the naked eye—bacteriology (băk-tē′rĭ-ŏl′ō-jĭ); with the structure of plants morphology In addition to these there are also many other fields of botany in which men have specialized—tiny areas in the great realm of "biology," the science of living things, both plants and animals.

BOTANY

Reading Unit No. 2

THE MYSTERIES IN A PLANT CELL

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How plant cells were first discovered, 2-6
What cells look like, 2-7-8
What we may find in cells, 2-8-9
How cells divide to form more cells, 2-9-10
What makes a plant grow? 2-10

Things to Think About

What instrument has helped us to learn the secrets of a living plant?
What single substance is found in every living thing on earth?
What are the building blocks out of which living things are made?
How does one cell become two?

Picture Hunt

Out of what microscopic units are these handsome Florida palm trees built? 2-6
What is the non-living part of a cell? 2-7
What kinds of cells are found in hardwood? 2-8
What kinds of cells are used in making flax? 2-8
What part of the cell is actively engaged in producing more cells? 2-9

Related Material

What substance in us makes us different from rocks and water? 2-279
Who gave us the "cell theory"? 2-279-80
What does the cell theory tell us about living things? 2-280

Leisure-time Activities

PROJECT NO. 1: Using any convenient and suitable materials, make a model of a plant cell, 2-7.

PROJECT NO. 2: Make charts or models showing how cells divide, 2-9.

Summary Statement

All plants and animals, big or small, are made up of tiny units called cells. Each cell consists of a cell wall or membrane, and protoplasm. All living things begin as a single cell, and by the repeated division of the cells, grow larger and larger.

Photo by Florida East Coast Rwy.

Who would dream, looking at these large and graceful palms, that they are made up of millions of cells so tiny that we can see them only with a microscope? All of them grow from single cells which divide again and again. The many cells arrange themselves into all the complicated parts of the trees.

The MYSTERIES *in a* PLANT CELL

There We Find a Substance Called Protoplasm, Which, though It Is a Good Deal of a Mystery, We Know to Be the Simplest of All Living Substances

IT WAS about three hundred years ago that the microscope—an instrument consisting of a lens or combination of lenses for making enlarged images of small objects—began to be developed. In the hands of curious men many objects, both living and non-living, were examined and studied.

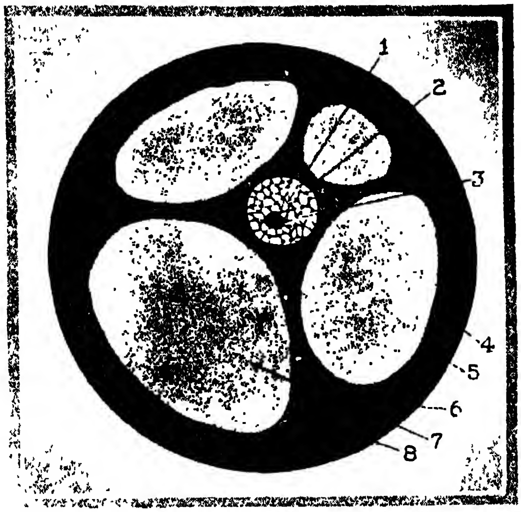
One of these men, Robert Hooke by name, happened to have a piece of ordinary bottle cork handy one day and decided to make sections of it to place under the microscope. He had no idea what he would see. With a very sharp knife he cut the thinnest sections he could and examined them under his microscope. Curiously enough, he found that the thin slices of cork were made up entirely of small compartments. Their size, shape, and arrangement reminded him at once of the cells of honeycomb, and so he called each compartment a cell. This name has been used ever since that time, although its meaning has been somewhat changed.

With further study, it was found that all living objects, whether animal or plant, whether large or small, were made up of either single cells or groups of cells. Many plants have been studied and much variation has been found. In small, simple plants, one or few kinds of cells may occur, while in large plants, such as maple and pine trees, many kinds are to be found.

In order that we may have a good understanding of a living cell, let us select a common type which may be found in all plants. We could very easily find one of this kind

near the center of a young stem of common clover. Usually it would have the general shape of an egg or football, with a tendency to become spherical. Because other cells press against it on all sides, however, its shape may be extremely variable.

For our study of the living cell perhaps it would be well to examine it from the surface to the center. The first part that attracts our attention is the outside, limiting layer of the cell; this is called the cell wall. It is a fairly rigid structure, sometimes very thick and sometimes very thin. When Robert Hooke first examined his cork sections, it was only cell walls that he saw. It happens that in cork cells, the other parts disappear when the cell becomes old. This cell wall holds the parts of the cell together. It acts very much like the skin covering of our bodies. In most of the living cells that have been studied, very tiny perforations can be seen in the cell wall. This would suggest that there may be some communication between living cells.



Here is a diagram of a cell which is alive and young but not so young as to be still dividing. The small oval bodies (8) are chloroplasts, which are the cell's food makers. They lie in the simplest part of the protoplasm (4) and are a special part of it. The nucleus (1) is another very special and more complicated part of the protoplasm; 3 is part of the nucleus called the nucleolus, and 2 is the boundary between the nucleus and what we call the cytoplasm. The cytoplasm, the green chloroplasts, or plastids, and the nucleus make up the living part of the cell. In addition you can see four very large lighter spaces, one of which is marked 7. These are the vacuoles, which hold various liquids; though they are not living, they are very important. The boundary of one of the vacuoles is marked 5; 6 is the wall of the whole cell.

As we look through the cell wall—most walls are transparent—we find that just under it lies a thin layer of material that is usually colorless. But with proper dyes it can be stained so that we see it better. Although this material has been given many names since it was first seen, it is now called protoplasm (prō'tô-plăz'm). It is this material which is all-important to the living cell, for in it is embodied the condition which we call life. All living objects possess protoplasm, with its very complex structure and organization.

If we could select a very fine sieve—it really would have to be a fine microscopic sieve—and strain protoplasm, we should find that it consisted essentially of two parts. The first part would be that which drained through the sieve—a material which is colorless in our living cell. If we wished to see it in more detail, we should have to stain or dye it. This is called cytoplasm (sī'tô-plăz'm). It is nearly transparent and usually has the consistency of a very thin jelly, although in many cases it may be rather rigid and firm. Ordinarily it would appear very much like the white of an egg and have many characteristics of that substance. For instance, if we heat cytoplasm as we should heat the white of an egg in boiling, it would coagulate and become hard and tough in much the same way.

The second part of the protoplasm is not able to get through the fine meshes of our microscopic sieve. Upon close examination, we find that this material is composed of a miscellaneous mass. Perhaps the most noticeable part would be the nucleus (nū'klê-ŭs). We may see it in this cell of the clover stem embedded in cytoplasm, appearing much like a full moon covered by a filmy cloud. Usually the nucleus is round or oval, and rather dark gray in color. Chemically it is different from the cytoplasm and can be distinguished from it by the use of stains which color it differently. The nucleus was first seen in certain cells of flower petals, and it seems to be an extremely important part of the cell. All young cells have nuclei (nū'klê-ī)—the plural form of "nucleus"—

although many lose them before they mature. In our present knowledge of cells, we know of no living cell which exists without a nucleus. It is all-important to the life of a living cell, for it seems to be the director of its activities and functions. Whenever great activity occurs in a part of a cell, the nucleus seems to be present in that part. You must not believe that the nucleus is constantly moving from one part of the cell tŏ another along a well-beaten path. Rather, the nucleus is held by cytoplasm in a more or less fixed position, although some change may take place.

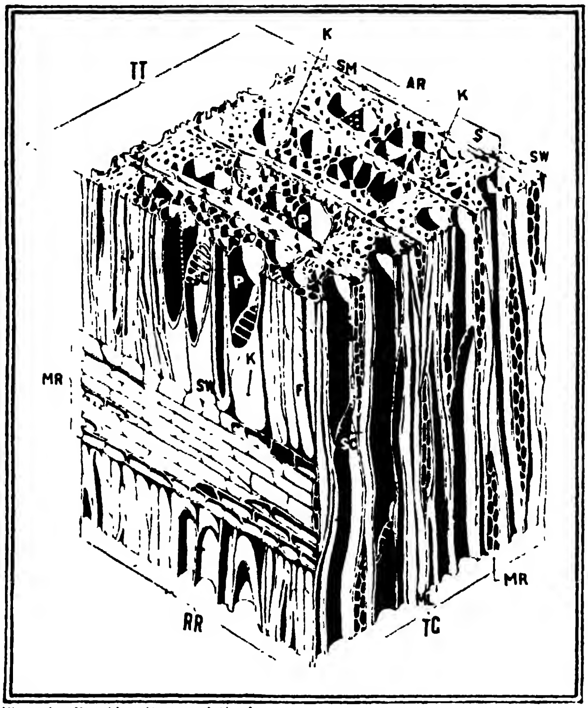


Photo by Brooklyn Botanical Garden

A cube cut from a hardwood tree would look like this under the microscope. Each one of those little divisions is a cell -- and as you see, the cells are of many different shapes. The plane marked by TT, or the upper surface of the cube, is cut horizontally across the tree. S is spring wood, SM is summer wood; and the area AR is a section of the annual ring, or one season's growth. Water runs through the large cells (P), which have pits in their walls (K). The fiber cells (F) are present only in hard wood.

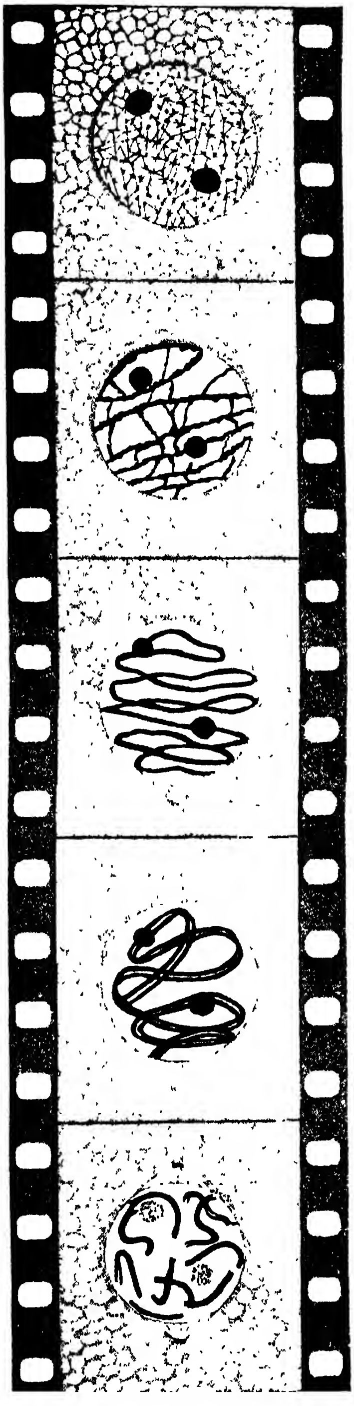
Others of these small objects that we may find in the cytoplasm are "plastids" (plăs′tĭd). These are small bodies which usually look very much like cookies. Plastids may be colored or uncolored. In the cell which we are examining, we may find some which are colorless and which aid in the storage of food material. These bodies are most frequent in leaves of a plant, and may be seen there as little green structures. These plastids are commonly called chloroplasts (klō′rō-plăst), and are green because they contain the coloring material chlorophyll (klō′rō-fĭl), which is very important in the manufacture of food for the plant. The number, distribution, and arrangement of plastids vary in different plants.

While other materials may possibly be caught by the microscopic sieve we have been using, not enough is known about them for description. Even specialists disagree as to the purpose and structure of some of these parts. It may be that with more study of protoplasm, other parts wil be found which may have a marked influence on our understanding of what we call "life" in protoplasm.

Photo by Brooklyn Botanical Garden

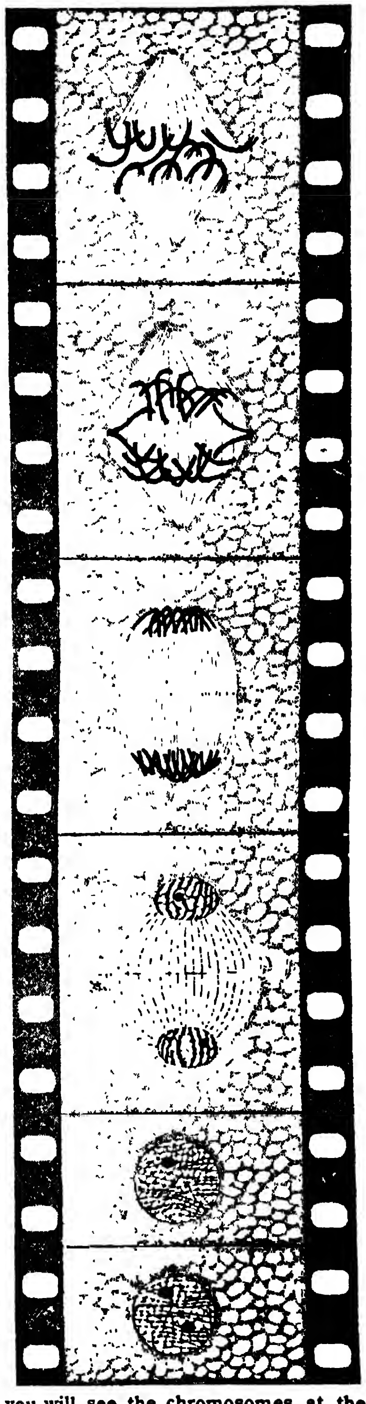
Here is a small piece of flax stem as it looks under the microscope. The large cells with the heavy black material between them are the ones which give us linen. These cells are dead, but their walls are very thick and flexible. They lie between the wood, at the bottom of the picture, and the outside of the stem, at the top. When we make linen we "ret" --or rot - away all the parts of the stem except the valuable fibers. The figures show the order in which the various cells break away and leave the part we make into linen.

So far, in this plant cell we have passed from the cell wall to the protoplasm. There remains a third part which is very important in the action of the cell. This part is called the vacuole (văk′ū-ōl). If we could have watched this cell when it was very young, we should have seen it completely filled with protoplasm. As the cell grew older, its



size increased as the amount of protoplasm increased. But the amount of protoplasm was not great enough to fill the inside of the wall, and an open space was formed in the center which filled with water. This water, with substances such as sugars and salts dissolved in it, is called sap. You probably at some time have broken a stem of a plant and found that from the broken part a watery material ran out. This would be cell sap, mostly from cells that had been broken. From the maple tree, by means of tapping, we ge a liquid which, boiled down, becomes maple syrup. Sometimes this is cell sap with much sugar in it, but the sap was not stored in the vacuoles of living cells. It comes from the water-conducting cells.

So far, we have learned only of the living cells of plants. Of course all cells when first formed are living. But later many of these cells die—that is to say the protoplasm dies and the cell contents disappear, though the wall remains. Many of these cells can do their most important work for the plant after they are dead. Take as an example the flax plant from which fibers are taken to make linen cloth. When young these fiber cells are living and contain protoplasm, but as they grow older



Here are diagrams taken from a moving picture film. They show the stages of a cell nucleus dividing. If you begin at the top of the column at the left, this is what you will see taking place: In the first two pictures the large nucleus is ready to begin dividing. In the next two the twisted thread, or spireme, has appeared. In the bottom picture of that column the spireme has broken into chromosomes. Now turn to the column at the right, and in the top picture you will see the chromosomes at the equator. In the next they have divided and separated. The last three pictures show the end of the process, with the wall first forming and then completed, so that at last two cells have come from the original one.

their walls become much thickened and the protoplasm disappears. Thus these fiber cells with their very thick walls prevent the stem from breaking in the wind and help it to stand upright. This general condition is also to be found in wood, especially in the newly formed wood. The sapwood of the oak tree, for instance, is composed mostly of dead cells. These dead cells not only give strength to the trunk of the tree but also serve as tubes through which water passes from the roots to the leaves.

What Makes a Plant Grow?

It would be impossible for us to leave our story of the living cell without brief mention of cell division— the formation of new cells. All of us have wondered how the bean or corn plant in our garden grows from a tiny seed to a large plant, how an acorn produces such a large oak tree. The increase in the size of the plant is due mainly to the production of new cells through cell division.

In the case of animals, growth occurs all over the body at the same time. A kitten, for instance, is born with all the organs and parts that it will ever have. As it grows to be a large cat, more tails and more legs and more noses do not develop. It grows with a single tail and a single nose, and as it grows these parts become larger. This is not the case with a plant, for in a plant the growth usually takes place in very definite regions. The increase in length of a stem or root, whether it be a main one or a branch, will take place at the tip. Most of us have seen men cutting off parts of the stem of a grape vine or a peach or apple tree. This is done to prevent the development of too many stems and too long ones. When this cutting is made, the tip of the stem is removed, and it is at the tip that cells are rapidly dividing during a growing season. Roots grow at their tips in the same way. In many plants, such as our woody ones, there is also a growth in the thickness of the stem or root. In these plants, just inside the bark, there is a layer of cells which are capable of rapid division. This layer is called the cambium (kăm′bĭ-ŭm), and it is very important to those plants that have "secondary growth"; that is, in which the stems or roots grow thicker. Any injury to it would be very harmful to the plant.

Since the cells from either the tip of the stem or the tip of the root are carrying on active division during the growing season, let us study a cell from either position in its dividing process.

How a Plant Cell Divides

These cells are generally completely filled with protoplasm and usually have no visible vacuole. The nucleus is somewhat larger than it is in the ordinary living cell. Before the cell divides, it grows much larger. And as it grows in size, so does the nucleus. After the nucleus reaches its largest size, a long thread, or spireme (spī′rēm), as it is called, is formed from its contents. It is very much the same as if we took a ball of thin clay and moulded it into a long, thin string

This spireme breaks crosswise into short pieces, each piece of which is called a chromosome (krō′mō-sōm). Chromosomes are very important structures, for we now know that they carry all hereditary characters and so are important in the breeding both of plants and of animals. The chromosomes vary a great deal in different plants, not only in size and shape, but also in number—the number being generally constant for each kind of plant.

The Splitting of the Chromosomes

Normally, after the chromosomes are formed they move toward the "equator" or middle plane of the cell and there form a single layer. While arranged along the equator of the cell, each chromosome splits lengthwise. Then each half of a single chromosome moves toward the opposite end of the cell. While these half chromosomes are actually moving to opposite ends of the cell, a new wall forms along the equator. After a new wall is formed, the parts of the original chromosomes on either side unite to form new nuclei. So in cell division we have first a division of the nucleus followed by the formation of a new cell wall between these nuclei. The two newly formed cells are exactly like the parent cell.

Reading Unit
No. 3

OUR MIGHTY FRIENDS, OUR DEADLIEST ENEMIES

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What causes some of our diseases? 2–12-13
The sizes and weights of different kinds of bacteria, 2–13-14
What bacteria look like, 2–14
Where bacteria live, 2–14-15
How bacteria reproduce their kind, 2–16
How bacteria are able to protect themselves against unfavorable conditions, 2–16-17
How some kinds of bacteria make life on this earth possible, 2–18-19
Useful bacteria, 2–19-20

Things to Think About

How can extremely tiny bacteria cause terrible diseases?
What prevents dangerous bacteria from getting into our bodies?
What would happen to us if all the bacteria on the earth were killed?

Picture Hunt

What do we call people who study bacteria? 2–13
Describe the shape of pus-forming bacteria, 2–14
What happens to dead trees that never decay? 2–16
Why did the camel's flesh disappear? 2–17
What was at one time the fourth deadliest disease in the United States? 2–17
Why must a bacteriologist in a laboratory be extremely careful? 2–19
What disease has modern science learned to control? 2–19

Related Material

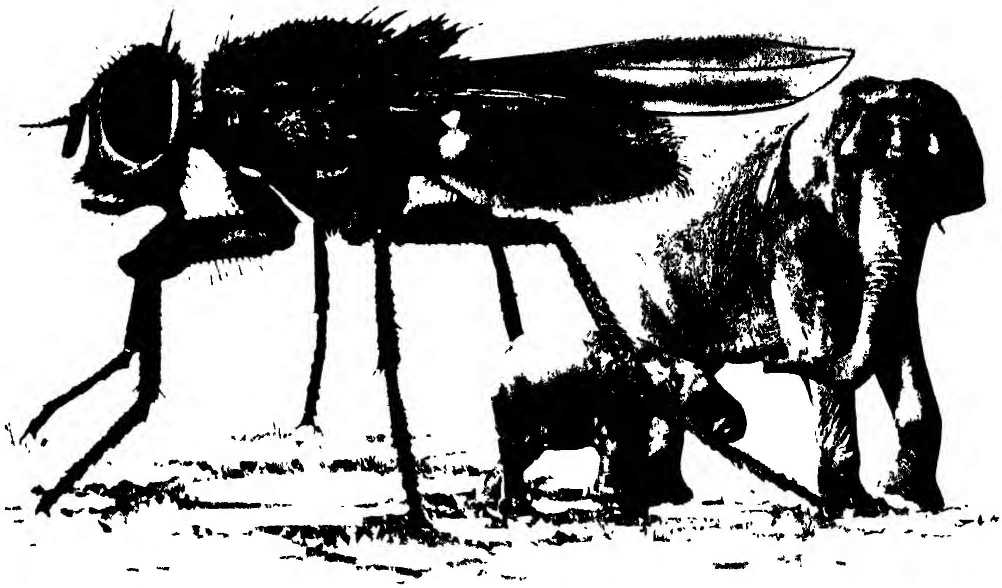
Who first discovered bacteria? 13–363
What makes milk turn sour? 9–341

Leisure-time Activities

PROJECT NO. 1: To learn how we control certain kinds of bacteria, divide some fresh milk into two lots. Put one lot into the refrigerator, and leave the other in a warm place. Which spoils first?

Summary Statement

Bacteria are so small that they can be seen only with a microscope. Most of our worst diseases are caused by bacteria that enter our bodies and multiply there. Fortunately, most bacteria are useful. They flavor foods, eliminate dead plants and animals through decay, and make our soil richer. We must constantly study bacteria in order to fight the harmful ones and make use of the useful ones.



Photos by British Museum and American Museum of Natural History

This picture will help us realize how small bacteria are; for the house fly that looks as big as an elephant has been enlarged only as much as many bacteria have to be enlarged if we are to see them at all.

OUR MIGHTY FRIENDS, OUR DEADLIEST ENEMIES

Though We May Not See Them, the Tiny Bacteria May Keep Us from Harm or Blot Out Our Lives

IF OUR eyes were microscopes (mī′krō-skōps), the world we live in would appear vastly different from the world we know, for we should be able to see millions and millions of living things now hidden from us. Among these tiny things we should find many mighty friends and deadliest enemies—the bacteria (băk-tē′rĭ-ȧ).

Bacteria are plants, the smallest and simplest plants known. They are sometimes called "germs," or "microbes" (mī′krōbs), names given to all living things that are too small to be seen without a microscope. The name, "bacterium," comes from a Greek word meaning "rod" or "staff." It is used when one plant is spoken of. Bacteria is the plural form, and is used when more than one is meant. Each bacterium is a drop of jellylike material, called protoplasm (prō′tō-plăz'm), surrounded by a wall. Some bacteria possess another, thicker covering called a "capsule" (kăp′sūl) In the protoplasm which forms the body there are many granules (grăn′ūl), or grainlike particles. The wall is smooth in some; in others there are short, hairlike parts projecting from it, called cilia (sĭl′ĭ-ȧ), or longer projections called flagella (flă-jĕl′ȧ). It is thought that these cilia and flagella help the bacteria to move about in liquids. The fastest of them move about four inches in fifteen minutes. No openings in the wall can be seen, but water and food pass through it into the body.

All bacteria are small, but some are smaller than others. The bacterium, or germ, which causes typhoid fever is so small that if 12,000 of them were placed end to end they would form a line only an inch long, and it would take many millions—about 111,000,000—to fill a hole the size of a match. Still smaller is the bacterium that causes influenza, usually called "the flu." It is scarcely half as

Photo by E. R. Squibb & Sons

A bacteriologist—a specialist in the study of bacteria—is at work in his laboratory. Because he is interested in the transmission of disease he may also study the viruses, which are not bacteria but do carry disease. They are too small to be caught and studied under a microscope. Here our scientist is injecting influenza virus into eggs in order that the unhatched chicks may yield us vaccine.

long and less than half as broad as the germ of typhoid fever. Look at your ruler and try to divide an inch of its length into 25,000 equal parts. Each of these parts is $\frac{1}{25000}$ of an inch—the length of the bacterium, or germ, that causes Asiatic cholera (kŏl′ĕr-å). Tuberculosis (tû-bûr′kû-lō′sĭs), or consumption, is caused by a bacterium only three times as big as the germ of Asiatic cholera. Some of the largest of the bacteria that are known are fifty times as big as the smaller ones, but even those large bacteria are so small that more than a hundred can be held on the point of a needle.

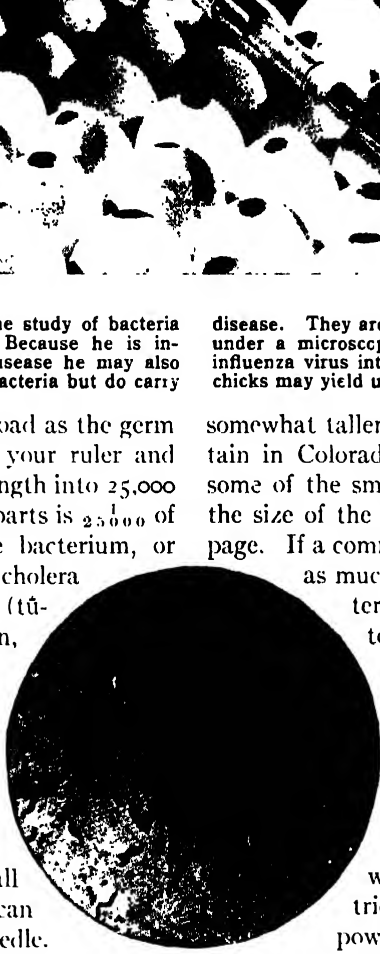


Photo by American Museum of Natural History

This picture shows the bacilli of typhoid fever, magnified and stained to make even the tiny, wavy flagella visible.

You can now understand that bacteria can be seen only with the help of a microscope, which makes them look much larger—perhaps more than a thousand times larger—than they are. For careful study of these small plants even greater enlargement is necessary. It has been said that if we could look at a man under one of our most powerful lenses he would appear somewhat taller than Pike's Peak—a mountain in Colorado; but under the same lens some of the smallest bacteria appear about the size of the periods and commas on this page. If a common house fly were magnified as much as one of the smallest bacteria must be enlarged in order to be seen, the fly would look as large as a large elephant.

It is hard for us to remember that the tiny plants are all about us. We forget them as we forget many important things in this world, especially things we cannot see—such as electricity. If we had eyes as powerful as microscopes we should doubtless have a much clearer idea of the world we live in.

Since the size of bacteria can be measured, it is not too hard to calculate their weight. Scientists who know a great deal about them tell us that 500,000,000 bacteria of average size weigh about one milligram, and it takes 30,000 milligrams to make an ounce. Now if you will multiply 500,000,000 by 30,000

you will see that it takes 15,000,000,000,000 —15 trillion—bacteria to balance an ounce weight.

When they are studied under a microscope it is found that bacteria differ in form or shape. Some are round, some are rod-shaped, and others are curved like a spring or corkscrew. The round ones are called "cocci" (kŏk′sī) in the plural, coccus (kŏk′ŭs) in the singular—from a Greek word meaning "berry." The rod-shaped ones are called "bacilli" (bȧ-sĭl′-ī)—singular, "bacillum" or "bacillus"—from a Latin word meaning a "stick" or "staff." The third group are called "spirilla" (spī-rĭl′ȧ)—singular, "spirillum"—from a Latin word meaning "coil." These three are the leading or fundamental (fŭn′dȧ-mĕn′-tăl) shapes, but there are many different kinds of cocci, of bacilli, and of spirilla, so that it is not always a simple matter to put each kind in its proper place. Usually only persons who have studied bacteria long enough to become quite familiar with many different kinds, can tell to which class a certain bacterium belongs; and no one can give a bacterium a name until he knows this.

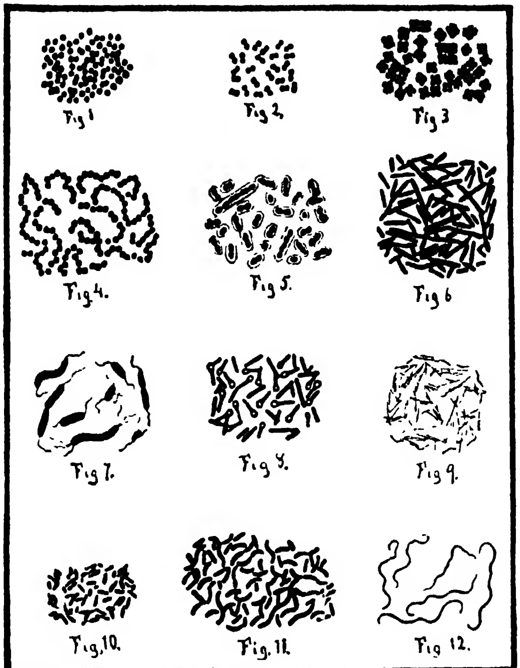


Photo by N Y. Botanical Gardens

This diagram shows some of the commoner forms of bacteria, of course greatly enlarged. 1. Spheroidal, or round, bacteria, a very common type which causes pus. 2. Spheroidal bacteria in pairs, an arrangement which makes them into "diplococci." 3, 4. Spheroidal bacteria in fours, and in chains. 5. Diplococci each surrounded by a capsule—the cause of pneumonia. 6. Typhoid bacilli. 7. Bacilli with "cilia," or tiny hairs. 8. Bacilli with spores. 9. The bacilli of consumption. 10. The bacteria of diphtheria. 11. The spirilla of Asiatic cholera. 12. The spirilla of recurrent fever.

Bacteria are found all over the world: they are in bogs, as well as in deserts; on high, bare mountain peaks, as well as in green, moist valleys; within the Arctic Circle, as well as in the Tropics; and on every continent and island, as well as in every pool, puddle, lake, stream, and ocean, in the world. They also live in and upon higher animals and plants. Hundreds of different kinds live in the food canals of insects, crawfishes, lobsters, and worms. When you remember that flies and mosquitoes are insects, and that they suck into their mouths liquids and juices in which bacteria live, you will readily understand how bacteria get into their food canals. It is easy for bacteria to enter the bodies of persons and of animals like the horse, the cow, the dog, through the mouth and nose, or by way of open wounds, cuts, or bruises. Many kinds live on the skin, especially on the skin of the hands and the face, and under the finger nails, where they cannot be easily dislodged. Certain dangerous bacteria live in the blood cells of animals with a backbone, which are called vertebrate animals. One very harmful species of bacteria causes a disease called tetanus (tĕt′ȧ-nŭs), or lockjaw in man, and another species causes anthrax in cattle. Within the bodies of human beings there are millions, and even billions, of bacteria distributed in the mouth, nose, lungs, and throughout the food canal. Some bacteria can live in places where there is no free oxygen, but others live in the air and require oxygen. Wherever life can exist, there are bacteria.

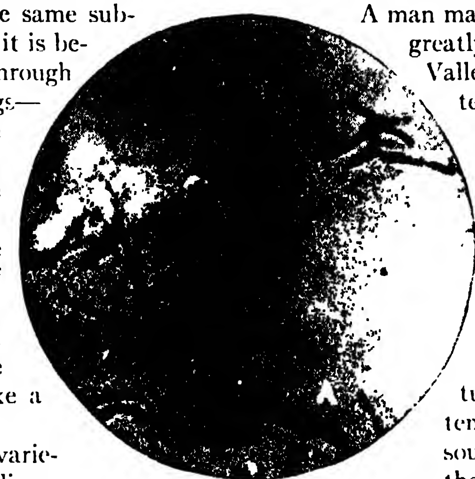
One reason for the fact that bacteria are found in almost every place in the world is their exceeding smallness. Because of this they need neither airplane nor parachute, but float freely in the air, up and down and in all other directions. Or they may travel on particles of dust, and be blown about on currents of air from place to place. In watery solutions or in fats or on moist sur-

faces of solid things, they move short distances by means of their cilia or flagella. You have already learned that both cilia and flagella are made of the same substances as their bodies; it is believed that they pass through minute pores—openings—in the cell wall. The cilia are shorter than the flagella and are curved only once, but the flagella often are longer than the body of the bacterium—even sixty times as long in some kinds—and unlike the cilia, are wavy, like a whip-lash.

Only a few kinds—varieties—of cocci possess cilia or flagella. Most of the bacilli and spirilla have them, but they do not all move at the same rate of speed. Some move slowly, some wobble, and others dart forward rapidly. In proportion to their size, we may say that some move with the speed of a trotting horse, others with that of an automobile or a locomotive.

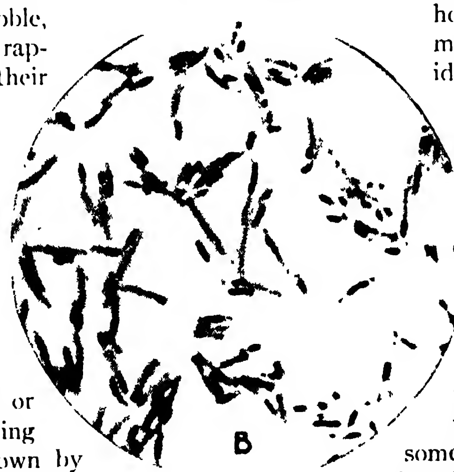
Besides moving from place to place, there is another kind of movement in some bacteria. This is an up-and-down or back-and-forth dancing movement which is shown by tiny particles when they are suspended in liquid or gas. It is called Brownian movement because a man named Brown first discovered it. This Brownian movement can sometimes be seen inside the cells of plants.

Birds and animals called mammals (măm'-ăl)—like the horse, cow, dog, and human beings—are warm-blooded; all other animals are cold-blooded, as we discover when we take up in our hands a frog, a fish, a turtle, or a snake. As long as warm-blooded animals, like ourselves, are free from disease their blood remains at the same temperature, whether they live in cold or in warm regions.



Photos by American Museum of Natural History

Here are two kinds of tuberculosis bacilli: above, that which causes the disease in human beings; below, that which causes it in cattle. Both, of course, are magnified.



A man may travel without suffering greatly from a place like Death Valley in California, where the temperature is 120° above zero Fahrenheit (fä'rĕn-hīt), to a region near the North Pole, where it falls to 60° or 70° below zero. The temperature of his body will remain the same. But if bacteria are taken to these places their temperatures will rise or fall to the temperature of their surroundings. This means that they will always be as cold or as warm as the medium about them. Certain kinds of bacteria thrive best in cold places, and others in warm or hot regions. One reason why many substances decay rapidly in hot weather is that certain bacteria that cause decay multiply much faster in warmth. When meat, milk, fruit, and other foods are kept on ice such bacteria do not thrive and so cannot multiply, or multiply very slowly.

There are bacteria whose home is in the soil, where they may be found sometimes from six to ten feet below the surface. Here their temperature ranges from 60° to 70° Fahrenheit. There are other bacteria that live in human beings and thrive best at the temperature of the blood, which is about 98.5°, but others thrive in hot springs where the temperature is from 140° to 170°. This shows that different bacteria have become adapted to very different surroundings, and that they have wonderful endurance as well; for all other living things usually die at a temperature of 140°. In birds there are bacteria that

Photo by U. S. Forestry Service

When any living thing has died, Nature's way of getting rid of it is normally to turn it over to the vast armies of the bacteria of decay. But once in a long time Nature plays strange tricks. She may turn boundless forests into coal instead of letting them decay. Or she may work a miracle of chemical change or substitution by which a log of wood disappears and in its place there is a log of stone. In the American Southwest are immense forests of these "petrified" trees, which never went through the regular processes of decay at all. Here is the largest tree in the Petrified Forest, Arizona. Even the part that is exposed to the air is a hundred feet long. There are other trees in the background.

live at a temperature of 102° Fahrenheit.

A bacterium may need only about a half hour to grow up in. If it then is warm enough and has plenty of food, its body divides into two parts by becoming narrower, or constricted (kŏn-strĭkt'ĕd), in the middle. This constriction becomes deeper and deeper until the plant is divided into two similar bacteria. These two bacteria at once begin to grow and in a short time, perhaps fifteen minutes or half an hour, each of them divides again, just as their parent did. In half an hour there may be four bacteria instead of the one we began to study. If each of these offspring divides every fifteen minutes for three hours, there will be more than four thousand bacteria instead of one. In twenty-four hours there will be so many that it is impossible for anyone to count them in a lifetime, for there will be twice as many as the number of seconds in a million years! In three days, or 72 hours, there would be so many that we should not be able to weigh them together, for they would weigh more than fifty steam locomotives! You will learn later how bacteria are prevented from multiplying so rapidly.

Germs That Live Years without Food

Many bacteria, especially the spirilla and bacilli, have a habit which enables them to live for years without food. Perhaps we shall be able to understand this habit of theirs better if we compare them with the seeds of some plants.

How a Seed Can Go to Sleep

If all seeds that fall to the ground in autumn should sprout as soon as conditions were favorable, the whole crop might be destroyed by an unlucky frost or drought. But seeds fall or are carried into widely differing places, many of them unfavorable. The seeds that do not find conditions suitable for growth can often enter a sleeping, or dormant, state, in which they may stay for a long time—perhaps as much as five hundred years for certain seeds. Many seeds are in this resting condition when they first ripen, and sometimes it is fairly hard to waken them and make them sprout. It is as if Mother Nature had put certain seeds to sleep in order to keep them safe for use at some future date, when times should be more favorable.

In a similar way many bacteria are able to live in times of great cold or great heat, of famine or of drought, by changing the protoplasm of their bodies into a tiny round ball and forming a thick wall around themselves. In this shape they are called spores.

A spore is not unlike the bacterium from

Photo by Grammstorff Bros

Even in the dry wastes of the deserts the bacteria do their work as scavengers. Already they have got rid of the flesh of this dead camel, and in time they will clear away its very bones. If they had not been busy for millions of years at this useful task, the earth would have been choked with its dead.

which it is made, but it has a thicker wall and there is less water in the protoplasm of its body. You see, it is well protected against unfriendly conditions. A spore is usually round or oval in shape and may be larger or smaller than the bacterium from which it was formed. It is able to live many years—nobody knows exactly how many, but probably more than a hundred—and it may be carried to any part of the world without being injured.

Most bacteria, like other living things, are killed when they are put into boiling water. But spores are not hurt by being kept in boiling water for some time, even as long as sixteen hours! Freezing kills or injures some bacteria; but many are not injured, and the spores can be frozen even in liquid air at 320° F. below zero and yet be as sound as ever. Neither do poisons harm spores, nor strong sunlight unless the spore is kept in the sunlight a long time. In that case the sunlight may destroy the spore wall. If at any time the spore finds its surroundings favorable, it can change back into a bacterium and continue to live as before. For these reasons it is hard to destroy certain kinds of bacteria. They are like the heroes in the fairy tales who led charmed lives and could not be killed or injured unless their one point of weakness became known.

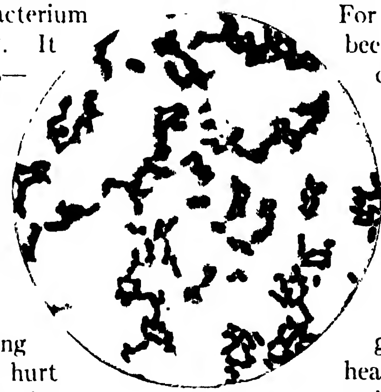


Photo by American Museum of Natural History

This is the diplococcus of pneumonia, which killed 83 out of every 1,133 people who died in the United States in 1930—more than were killed by any other disease except cancer, heart disease, and nephritis.

For many years experiments have been made in the hope of discovering a light which does not also produce heat. You know that an electric bulb produces heat as well as light. A kerosene lamp, a candle, a gas flame, or a match flame, all give heat as well as light. The sun, which is our greatest light-giver, is also our greatest heat-giver. But there are bacteria that give light with very little heat, like that on the glow-worm, the firefly, the centipede, and certain animals that live in the sea. How this light is made is not perfectly understood, but it has been called phosphorescence (fŏs′fŏr-ĕs′ĕns), because it shines with a greenish-white light in the dark, like a substance called phosphorus (fŏs′fŏr-ŭs). It is thought to be the result of a slow burning called oxidation (ŏk′sĭ-dā′shŭn), which takes place in the bodies of these animals and plants. Phosphorescence is not always dependent on life, for the dried and powdered

abdomen of a firefly will give this light if there is air and moisture around it.

There are said to be twenty-eight different kinds of bacteria that are light-producing, most of which, though not all, live in the sea. Sometimes the light they give, together with the light of a tiny animal called Noctiluca (nŏk'tĭ-lū'kȧ), causes the waters of the sea to shine with such splendor that the reflection of the stars above is dimmed! These light-giving bacteria are sometimes found on animals, whose bodies are outlined, in this way, in a glow of light. A single bacterium of this sort is so tiny that it cannot be seen, but in masses they are clearly visible. Such bacteria have to have oxygen and moisture if they are to keep alive.

These luminescent (lū'mĭ-nĕs'ĕnt), or light-giving, bacteria can be grown on certain kinds of foods in laboratories when there is oxygen for them to use; and these growths may be photographed by their own light. It is not known if the light is useful to the bacteria themselves or to other living things.

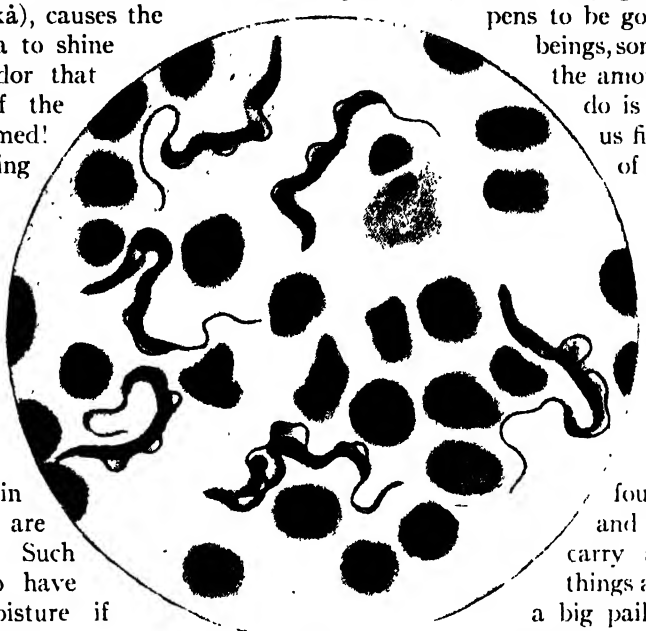


Photo by American Museum of Natural History

These are trypanosoma protozoans, microscopic animals that cause sleeping sickness, a terrible disease that rages in parts of Africa, where it is spread by the tsetse fly.

Plants That Are Friends and Enemies

Interesting as bacteria are in themselves, the things they do are even more interesting. When fields are plowed or when wheat is made into flour or when iron and coal are dug from the earth out of a mine, we say that useful work is being done. When houses are burned, machines broken, or when grain is destroyed by a storm, we say harmful things are done. Some bacteria, although they are so very small, can do more good work than many plowmen or millers or miners. But some bacteria do more harm than a big fire or even a terrible storm can do.

This may seem strange to you, but if you care to study these strange plants you will find it true. Not that they mean to do either good or evil; but as long as they are active they must have food. Sometimes the process by which they get their food happens to be good for us human beings, sometimes bad. But the amount of work they do is very great. Let us first consider some of the things they do that are good for us.

The man who removes waste from our homes and lawns is called a scavenger (skăv'ĕn-jẽr). But men scavengers are found only in cities and towns, and they carry away only such things as can be taken in a big pail or loaded on a wagon.

There are bacteria that get their food from such waste matter as dead animals and plants. As they eat and grow, they cause a change to take place in the waste substance, so that it can be taken into the soil and into the air. There is then no need for men scavengers to carry away the waste. This change which is brought about by bacteria is called decay, or decomposition (dē-kŏm'pō-zĭsh'ŭn).

But the decomposition that is brought about by the bacteria does more than dispose of unsightly waste on the earth. Indeed, it does the earth much good, for, as you know, the earth is very old—millions and millions of years old—and since it gives food to so many plants it would grow less fertile if no new food materials were put back into it. The work done by the bacteria changes waste materials into the same materials that the earth gives to plants to make use of as food. By putting this back in the soil

Photo by American Museum of Natural History

Here is some of the apparatus of a modern bacteriological laboratory—microscope, test tubes, siphon, gas flame, and various other things. If you have never work‸d in a scientific laboratory, you will hardly be able to guess how clean everything has to be, how skillful and accurate must be every movement.

and air the bacteria help provide food for plants. That is the reason why plants can grow up out of the earth, year after year, and always get enough minerals. We shall learn more about this later. At present there is more to be learned about the decay which the work of bacteria brings on.

Most changes that bring about decay also produce heat. In the decay of manure, which is barn-yard waste, there is so much heat that gardeners use it for hurrying, or "forcing," the growth of many kinds of plants. Because of this work of bacteria we are often able to enjoy beautiful flowers or tender green vegetables that come from our gardens much earlier in the spring than would otherwise be possible. In some materials it is even possible for a fire to result from the work of bacteria in bringing about decay. Fires which no person has lighted sometimes occur in hay that has been put away in sheds or haylofts before it is entirely dry. The heat caused by the decomposition of the hay by bacteria may break out into a fire which burns up all the hay and also the shed or barn in which the hay is stored. Such a fire is said to be caused by spontaneous combustion (spŏn-tā'nê-ŭs kŏm-bŭs'chŭn).

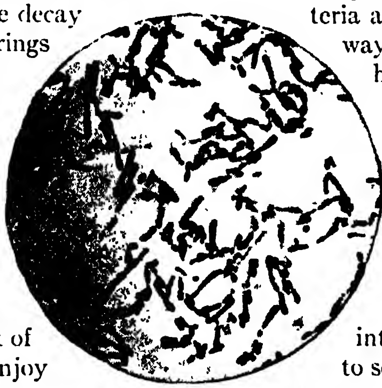


Photo by American Museum of Natural History

Here is a picture of the bacillus of diphtheria, a disease which modern science has done wonders to bring under control.

Besides acting as scavengers in clearing away dead plants and animals, many bacteria are of great use to us in other ways, either alone or with the help of their cousins, another class of plants that possess no green coloring and are called fungi (fŭn'jī). Bacteria and fungi cause fermentation (fûr'mĕn-tā'-shŭn) in many liquids. Fermentation changes cider into vinegar, and grape juice into wine. It also causes milk to sour and dough to rise. Without the fermentation of yeast in dough we should not have light, delicious bread.

Man has not always known that it was fungi and bacteria that did this work. More than seventy-five years ago, a great scientist whose name was Louis Pasteur (pås'tûr') discovered that bacteria cause milk to sour. Then another scientist discovered that it is a particular kind, or species (spē'shēz), of bacteria which causes the souring. It makes, or produces, an acid which he called lactic

(lăk'tĭk) acid; and the bacteria which sour milk were called lactic acid bacteria. The greater the number of these bacteria in milk the sooner it sours, because a greater amount of lactic acid is produced. If the milk is kept in a cool place, such as a refrigerator, at 50° Fahrenheit it is a good deal longer in souring. Whenever the lactic acid bacteria, or "lactobacilli" (lăk'tō-bá-sĭl'ī), as the scientists call them, work in milk, heat is produced; this hastens the souring.

How Bacteria Help to Make Cheese

Bacteria are helpful in cheese-making and in butter-making. We should not be able to enjoy the fine cheese we can buy at the market if there were no bacteria to aid in making it. Differences in the type of cheeses depend largely on the fact that different yeasts, molds, bacteria, and other organisms have been at work in the ripening cheese. Sometimes the bacteria are added to the milk before the cheese is made.

The work of bacteria is of use in making other food substances besides butter and cheese. Vinegar, cider, and sauerkraut cannot be made without the help of bacteria. Cattle in cold climates would have no green food in winter if there were no bacteria to ferment and cure silage (sī'lāj), which is made of green corn, millet, and other plants. Without bacteria much of the food eaten by cattle would be wasted; for it is due to the work of bacteria living in the food canals of cattle that the cell walls of the food the animals have eaten are changed into sugars which, of course, can be used as nourishment.

How Tobacco Gets Its Flavor

Bacteria are depended on to give flavor to certain kinds of tobacco. When the tobacco plants are cut down the leaves are cured by being heaped up in great piles so as to produce heat and fermentation. This fermentation is in part what produces the flavor.

Some kinds of bacteria are helpful in the production of clothing. In preparing flax from which linen is made, bacteria aid in separating the fibers, which are then spun into threads. No other way of separating flax fibers has been discovered; if bacteria did not do this work for us we should have no linen.

The powdery blue dye stuff called indigo is prepared by bacterial fermentation of indigo plants that grow in warm countries. Sponges are prepared for use with the help of bacteria, which also help in a good many of the processes used in our modern industrial plants.

It is believed by scientists that bacteria which lived long ago helped to change the wood of fallen trees into coal. Even now, in many places where plants are covered with water, sand, and mud in the colder regions of the earth, the bacteria are busily engaged in decomposing the wood.

You have already learned that soil is made by the crumbling of rocks into powder. But who would guess that such tiny plants as bacteria are able to help in crumbling rocks? This is true, nevertheless. It occurs in this way:

Living on a Rock

Some kinds of bacteria live on the bare surfaces of rocks, where they can make a satisfying dinner out of substances that we should never think of as being food for any living thing. After getting their food they make certain acids which soften the materials in the rocks. Then when the rain falls some of the loose particles of rock are washed away, and the water sinks into the little hollows or openings that have been made. In cold climates in the late autumn or early spring, a rain may be followed by a frost, and the water in the hollows, or pores, of the rocks freezes. As everybody know, water expands—swells—and takes up more room when it freezes. So as it freezes it cracks the rocks in some places and breaks off pieces in others. The pieces fall and break up into still smaller parts until bits of sand and soil are formed.

Since most of the plants that give us our food cannot live without soil to grow in, and since all animals, including man, need plants for food, it is easily seen that the help of bacteria in making soil is valuable.

Bacteria, however, do much more in the way of making soil than to help break up rocks. Soil made only of sand or particles

of rock cannot furnish certain foods for all kinds of green plants. There must be in it other substances which the plants can use for food. The work of bacteria helps to provide some of those other substances.

The most important work of bacteria is in helping green plants to obtain nitrogen (nī'trō-jĕn). All plants need this substance to build and to repair the material in their cells. The air is Nature's great storehouse of nitrogen; but green plants cannot take it from the air nor use it free from other substances. Certain bacteria, however, can take it from the air, join it to other substances, and in this form give it to the green plants to use. There also are bacteria that are able to live upon dead plants which are found in marshes and pools. In doing so they free carbon dioxide (dī-ŏk'sīd). The bacteria return this gas to the air; and green plants can take it directly from the air and use it in making food. The oxygen is left in the air for the use of animals and human beings in breathing. There even are bacteria that are able to change pure sulphur into compounds which are used by plants.

You now understand that some of the bacteria in the world are man's greatest friends. Without them life as we know it would become quite impossible. There are other bacteria, however, which are man's deadliest enemies. Against these he must be continually watchful. They enter his home and leave sickness and death. They cripple or kill smiling babies and laughing boys and girls, as well as aged men and women. They attack the flowers in the garden until they droop and die. They devastate the fields and orchards like a fire which wastes and destroys. They invade pastures and kill cattle, sheep, horses, and hogs. They go with children to school, grown people to church, and soldiers into the tent or barracks. These deadly enemies are everywhere; and they are quick to begin their deadly work. They are busy summer and winter, spring and autumn.

There are not so many enemy bacteria as friendly bacteria. If there were, human beings would probably perish from the earth. These enemy bacteria cause a variety of diseases that work havoc among men. Pneumonia (nū-mō'nĭ-ȧ), scarlet fever, whooping cough, tuberculosis, lockjaw, diphtheria, typhoid fever, blood poisoning, dysentery, and syphilis are a few of them.

In olden times, before we had learned about infection, hundreds of thousands of people died of the plague (plāg). Thousands died of yellow fever and malaria, which we now know are caused by certain very tiny animals. Measles and scarlet fever carried off thousands of little children in certain years. These diseases would sweep like a fire over an entire country, sometimes over many countries, and leave sorrow and suffering behind.

Fortunately, we have now learned how to prevent or to control many of them. A day may come—let us hope it is not far distant—when all these deadly enemies of man will have been destroyed.

In their lowest forms plants and animals are so much alike that it is hard to draw a sharp line between them. The strange-looking object at the right is an amoeba (ȧ-mē'bȧ), the simplest form of animal. Like the bacteria it is made up of a single cell so tiny that we must have a microscope to see it. Its cell wall is very thin. It is just a blob of protoplasm, with a tiny body known as the nucleus (nū'clē-ŭs) somewhere near its center. That part of the protoplasm which lies outside the nucleus is called the cytoplasm (sī'tō-plăs'm). It in turn is divided, though by no clear dividing line, into ectoplasm and endoplasm. The ectoplasm is the clearer protoplasm that lies toward the edges of the little creature. The endoplasm is the denser, more granular protoplasm toward the center. The amoeba moves by just flowing along. It sends out blunt projections of protoplasm that are known as pseudopodia (sū'dō-pō'dĭ-ȧ)—"false feet"—and then the rest of the animal follows. It is constantly changing its shape. It eats by simply flowing around its food; and when it multiplies, it does so by dividing in two. The nucleus divides first, and the rest of the cell then pulls apart to form two new cells, each with its own nucleus. The amoeba belongs to the groups of animals known as Protozoa (prō'-tō-zō'ȧ). They contain the lowest forms of animal life.

Reading Unit No. 4

THE STRUCTURE OF A PLANT LEAF

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What leaves are, 2-23
The work done by leaves, 2-23-24-26
The different shapes of leaves, 2-24
The beauty of leaf veins, 2-25
What a leaf looks like inside, 2-26

Things to Think About

Of what use are veins to leaves?
How does the shape of leaves help us to learn their names?
How do gases enter and leave a leaf?
How does water get into a leaf?
What makes leaves look green?

Picture Hunt

Name some trees which keep their leaves all winter, 2-23
Name a tree with pinnately compound leaves, 2-24
How many simple leaves are shown in the picture? 2-25
What group of cells in a leaf looks like a fence? 2-26
What are the thick lines in a leaf called? 2-26

Related Material

How do plants breathe? 2-49
How do plants make the world's food? 2-41-44
Why are green leaves called "sugar factories"? 2-41

Leisure-time Activities

PROJECT NO. 1: Make a labeled collection of leaves, showing both simple and compound leaves, 2-25.

PROJECT NO. 2: Make a scrapbook showing the veins of decayed leaves, 2-25.

PROJECT NO. 3: Make a plaster cast of a leaf pressed into plasticene or clay.

PROJECT NO. 4: Using a leaf as a negative, make a photographic print of the leaf, 10-446-52.

Summary Statement

Leaves are not only the sugar factories for plants, but because of their graceful shape are also objects of great beauty. We can easily identify our common trees because their leaves have distinctive shapes.

Photo by Cornelia Clarke

When winter comes most of the trees stand bare and gray against the sky, and the crisp snow lies in ridges along their branches or in a soft blanket around their trunks. Where are the leaves then? Well, some of them—those of the deciduous trees, such as oaks, maples, and birches—have fallen and drifted away; but others—those of the evergreens, such as pines and firs—are on the trees still. For we must not forget that the sharp green needles of the pines are really leaves, though of an unusual shape.

The STRUCTURE *of a* PLANT LEAF

Here You May Learn of the Amazing Service That Leaves Can Render a Plant

IN ALMOST every group of plants we find that the part of the stem that is in the air bears outgrowths at the sides. These are usually flattened, and most of us usually call them "leaves." Yet when we look at one of them from the moss plant and compare it with one from an oak, we find differences. While both may serve the plant in the same way, their structure is very different. Perhaps the outstanding difference is the presence of veins in the oak and not in the moss. These veins form the vascular (văs'kū-lăr), or conducting, system which carries water and salts into the leaf and food out of it. This difference between the leaf of the oak and the leaflike structure of the moss, together with other differences, clearly distinguishes the one kind from the other. It is only those outgrowths possessing a vascular system that we are willing to call true leaves. It is only these that we are now interested in.

The most complete foliage leaf has three distinct parts: the blade or flattened portion, the petiole (pĕt'ĭ-ōl) or leafstalk, and the appendages at the base of the petiole which are called stipules (stĭp'ūl). If a plant has any part of a leaf at all, that part is usually the blade, even though the other parts may be lacking. When the blade is not attached to a petiole, it comes directly from the stem. The leaf is then said to be sessile (sĕs'ĭl).

The spread-out leaf blade provides a surface important for the taking in of light

energy and for the exchanging of gases between the leaf and the atmosphere. And, as you will find in our story about how a plant gets its food, this exposure to light and the gas exchanges between the leaf and the atmosphere are extremely important to the plant and indirectly to man, as we shall see later on.

It is on the basis of their blades that leaves are divided into two general classes—simple and compound. "Simple leaves" are those in which the blade is unbroken, as in the maple and the oak and the violet. "Compound leaves" are those in which the blade is broken up into smaller portions called leaflets, as in the locust and ash and horse chestnut. When the leaflets are all attached directly to the end of the petiole, the leaves are said to be "palmately (păl′-mât-lĭ) compound." The leaflets radiate from a center somewhat like the fingers from the palm of your hand. This is the case in the horse chestnut and clover leaves. But in other compound leaves the petiole extends into a slender, stemlike axis from which the leaflets arise. This type is called "pinnately (pĭn′ăt-lĭ) compound" and is found in most of the ferns, walnuts, ashes, locusts, and roses.

Photo by Davey Tree Expert Co

This is a black-locust leaf. It is a good example of a compound leaf of the pinnate type.

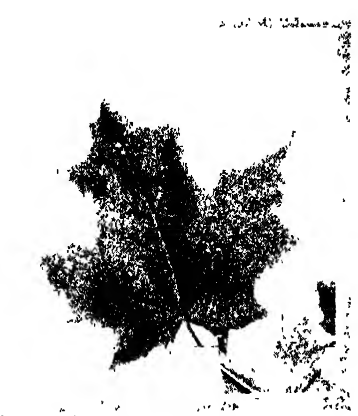


Photo by Davey Tree Expert Co

This sugar-maple leaf is a good example of a simple leaf, rather deeply cleft. The squares in the background of each picture above give us an idea of the size of the leaves shown, for each square originally measured an inch.

Leaves, both simple and compound, vary considerably in size and shape. Some of the palms and tree ferns of the Tropics have compound leaves which may reach fifteen to twenty feet in length. Other plants, like many of those of bogs and heaths—cranberries and heather, for instance, which are residents of northern countries—develop small, simple leaves that are hardly over half an inch in length.

The shape of the leaf or leaflets may vary greatly. It may be oblong or oval or ovate or kidney-shaped or lanceolate (lăn′sê-ō-lât)—long and slender like a lance. Though in some cases the shape of the leaves makes it possible for us to distinguish certain plants quickly, in others the differences are so great that it is impossible to use shape as a means of classification.

The margin or edge of leaves may be of many kinds. It may be smooth, as in many grasses, iris, and onion. Or it may be variously toothed or lobed, as in oak, rose, apple, cherry, maple, elm, and other plants. In the oaks especially there is a great variety in the size of the teeth and lobes. The botanist uses many different terms to describe these differences in the nature of the leaf margin.

The petiole, when there is one, is truly a leafstalk. It serves to hold the blade in a position where it may act to best advantage. In it are to be found vascular bundles through which materials pass into the leaf from the plant and out of the leaf into the plant. The petioles of many plants are able to increase in length and twist and curve, thus allowing for change in position of the blade, giving it better exposure to the light.

When stipules are present, they may be useful to the plant in various ways. In such plants as the oaks, beech, tulip tree, and elm, they serve as bud scales, and when the buds grow they drop. In plants such as roses they are permanent. Some of them look like leaflets and function—or work—as such along with the leaf. Sometimes, as in one of the members of the pea family, the stipules have taken over the usual work of the blade, which is reduced to a tendril. More often they bear no resemblance to blades. Perhaps you have noticed the stipules of the thorny locust and the barberry, which develop into prickles that aid in protecting the plant from animals. The stipules of smilax

Photo by Cornelia Clarke

Have you ever really looked at leaves? Did you have any idea that they were made in so many different designs and every design so beautiful? How many of these leaves can you name? They are mostly from deciduous trees, and you must have seen many of them often. Again, can you pick out the different types of them, as they are explained in this story—simple and compound, palmate and pinnate?

and similar vines change to clinging tendrils which help the plants to climb.

Leading into the leaf blade from the petiole are the vascular structures called veins. In most leaves they are nearer the lower surface than the upper, and look very much like the veins on the backs of our hands. It is through these veins that materials pass into and out of the leaf. The arrangement of the veins in the leaves does not vary a great deal.

The Beautiful Patterns of Leaf Veins

There are two general types of venation (vē-nā′shŭn), or veining, commonly found in leaves: the parallel venation and netted venation. If you have ever held a grass leaf up to the light, you have noticed that the main veins run parallel with one another for the entire length of the leaf, coming together toward both ends. This is the type of venation found in most monocotyledonous (mŏn′-ō-kŏt′ĭ-lē′dŭn-ŭs) plants, to which group belong our grasses, sedges, lilies, and orchids. If the veins that can be seen by the naked eye branch frequently and join again, forming web patterns, the leaf is said to be net-veined. There are two types of net-veined leaves: those whose prominent veins branch from a strong midrib or central vein, as in the willow and birch and apple and lilac; and those having several large veins beginning at the top of the leafstalk and radiating like the rays of a star. The first is generally known as a pinnately veined leaf and the second as palmately veined leaf. In both cases there are plenty of small veins which unite the larger veins. If you have ever looked at a partially decayed leaf, you have seen how complete this may be.

The Wonders Inside the Leaf

So far we have been looking at only the outside appearance of the leaf and its variations. A truly fascinating study is one of the internal parts of the blade. Just how cells can be so neatly arranged is astonishing. Suppose that we take the blade of the com-

mon privet leaf and make a very thin section across it, one that can be studied under the microscope. The section must be very thin and carefully handled or it will not be good for study.

We find that the outermost layer of cells forms a complete covering for the leaf—it seems almost like a case in which the inside cells have been carefully placed. It compares with the skin covering of our bodies, and is known as epidermis (ĕp'ĭ-dûr'mĭs). If we look closely we find that in the surface layer there are small openings or pores. Each one of these openings is called a stoma (stō'må)—stomata (stō'må-tå) in the plural -and these allow for the gas exchange between the leaf and the surrounding atmosphere. It is also through these that water is lost from the plant. Two cells, called guard cells, immediately surround each stoma. When seen in surface view, these guard cells are usually broadly crescent-shaped or almost semicircular. These cells serve effectively in regulating the amounts of gas passing through the pores by increasing or decreasing the size of the opening. Covering the surface of the epidermis, except the stomata, is a layer of waxy material which is secreted (sê-krē'tĕd), or made, by the epidermal cells. This layer, called cuticle (kū'tĭ-k'l), is waterproof and partly gas-proof, and is effective in checking the loss of water from the leaf.

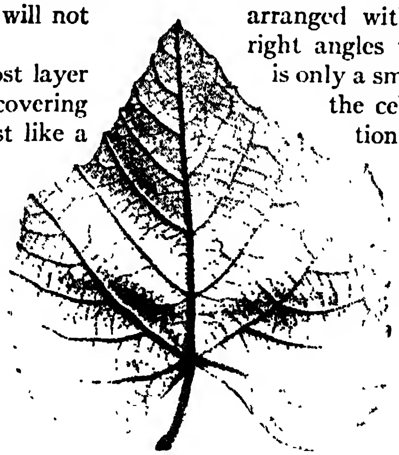


Photo by Cornelia Clarke

In this photograph of the lower side of a grape leaf the main veins stand out sharply, and between them we can trace the delicate network of finely branching little veins.

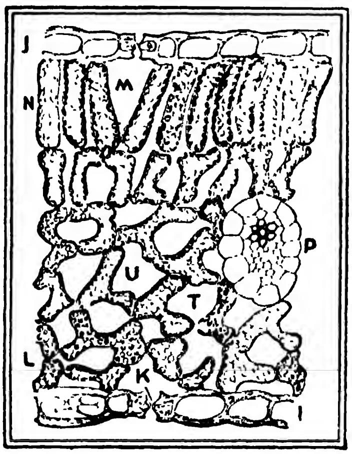


Photo by N. Y. Botanical Garden

In this diagram of a cross section of a leaf we can pick out all the different sorts of cells of which this story tells. J. Upper epidermis. M. Substomatal cavity, just below stoma. N. Row of palisade cells containing rounded chloroplasts, in which is green chlorophyll. I. Lower epidermis. K. Stoma in lower epidermis. L. Spongy cells containing chloroplasts. P. Vascular bundle, or vein, in cross section. T. and U. Intercellular spaces.

Under the top layer of the epidermis—though not in the veins—are masses of thin-walled cells which we refer to as "mesophyll" (mĕs'ô-fĭl) cells. In the privet leaf, as in many leaves, the arrangement of the upper layer of "mesophyll" cells is different from that of the rest. They are arranged with their long dimensions at right angles to the epidermis, and there is only a small amount of space between the cells. Because in a cross section of the leaf they appear like posts standing close together, they are called "palisade" cells. Underneath the palisade layer, we find the cells very irregular in shape, with large spaces between, presenting a very loose structure. They are fittingly called the "spongy mesophyll" cells.

The veins of the leaf are made up of the same kinds of conducting cells that we find in the stems and roots. They consist mostly of xylem (zī'lĕm) cells, which form long tubes that carry water, and phloëm (flō'ĕm) cells, which carry foods. They are frequently covered by a layer of cells forming a sheath. Their importance in conducting materials cannot be overemphasized. Without the xylem tubes that carry water to all parts of the leaf, a broad leaf would quickly wither on a bright day. And without the food conducting phloëm cells, the food would not get out of the leaf to other parts of the plant that cannot make their own food.

You may well wonder about the green coloration of the leaf. The green color is due to the presence of chloroplasts (klō'rô-plăst), in which there is the pigment, or coloring matter, called chlorophyll (klō'rô-fĭl). It is uncommon to find the chloroplasts in the epidermal cells; it is the palisade cells that contain the most.

Reading Unit No. 5

WHAT A PLANT STEM DOES

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What a stem is, 2–28-32-33
What stems do for plants, 2–28-32
What a stem looks like inside, 2–29-30
How a stem grows in thickness, 2 30
How bark is made in a tree, 2–30-31
How certain stems can reproduce the whole plant, 2–32-33
Why some plants have spines, 2–33

Things to Think About

Why do stems grow tall?
What part of a tree is used for wood?
How can one tell the age of a tree?
In which part of a tree are foods carried back and forth?
Why does peeling off the bark of a tree often kill it?
How do tree trunks breathe?
Why are some stems soft and not woody?
What stems always grow underground?

Picture Hunt

How long did the sequoia tree live? 2–28
Why do lumbermen peel off the bark of oak trees? 2 -29
About how old is the tree trunk which you see cut across in the picture? 2–29
How can a tree be killed without cutting it down? 2–30
What part of the potato stem do we eat? 2–31

Related Material

What products do we get from trees? 9-245-58
How are logs made into wooden planks? 9-251-56
How many acres of forest did our country once have? How many have we to-day? 9 257

Leisure-time Activities

PROJECT NO. 1: Find a tree stump, and estimate its age by counting the annual rings, 2–29-30.

PROJECT NO. 2: Dig up some weeds and locate the underground stems, 2-32.

Summary Statement

Plant stems keep the leaves turned toward the sunlight. They also carry food up and down the plant, and carry water from the soil to all the cells in the plant. Woody stems supply the world with lumber. Many other stems give us food.

What a pity it is that a giant sequoia such as this one, which had been growing for 1,341 years, should ever be cut down! But once in a while one has to be felled, and then we can count its "annual rings" of growth and see just how old it is.

Photo by American Museum of Natural History

This ancient tree not only tells us its age, but adds much other information. We can note how thick each annual ring is, for instance, and judge from the tree's growth each year something of the history of California's climate in ages past.

WHAT *a* PLANT STEM DOES

For Various Kinds of Work, Plants Have Developed an Amazing Variety of Stems

NEARLY all of the plants that you commonly see are made up of two main parts, the shoot and the root. The shoot is that part which is usually above ground and bears leaves, while the root usually is to be found underneath the ground. Where the stem ends and the root begins is hard to tell, and you could never be sure as to the exact region by examining it from the outside. Now we are interested in the stem and all the forms it may take, and we shall examine those kinds which we see most frequently, such as the ones on our common trees and herbs.

It is the stem which supports the leaves and holds them out like tiny flags into space, where the greatest amount of light may strike them. This is an important task, especially in large trees where there may be as many as half a million leaves. Besides acting as a support for leaves, the stem conducts materials of many kinds. It conducts water and mineral substances from the root to the leaves, and carries the food manufactured in the leaves to the root. Sometimes the food has to be carried as far as three hundred feet, as in some of the redwood trees of the Western United States. In order to see how the stems can carry it we must look at their structure from the inside.

One kind of stem that we see every day is that of such woody plants as the oak. It is not all wood, as we might suspect from looking at logs in a lumber yard. Suppose we cut across the stem of an oak tree and examine the parts.

Photo by U. S. Department of Agriculture

These lumbermen have cut down a big stem of the tanbark oak in California. The bark of this tree, which is unusually thick, is used to tan hides into leather. You will notice how cleanly the bark can be separated from the woody part of the stem; it is done between layers 3 and 4 in the picture below.

In the very center of the oak stem is a part which one does not usually see plainly. It is only about the size of a pin and very indistinct; it is called the pith. Even woody stems, as well as most other kinds, have a pith, though usually not a very noticeable one. Yet there are some woody stems which are exceptions; the elderberry and the sumac, for example, show a rather large pith.

The pith is surrounded by what we know as wood—the botanists' name for this is xylem (zī'lĕm). This wood is the most noticeable part of the stem; and the outer part is different from the inner. The inner part is called heartwood, and happens to be the most valuable part of the tree to the lumberman.

Photo by Cornelia Clarke

If we cut straight across a black-oak stem this is what we see. The pith is at 1; 2 is the heartwood, 3 the sapwood, and 4 the phloëm and true bark. Each pair of circular bands represents an annual ring, and the radiating white lines are the wood rays of living cells.

It can no longer carry materials, but aids in giving strength and hardness to the stem. Heartwood is harder than the rest of the wood; and in most of our trees, gums and mucilages are stored in its cells.

The younger wood is called sapwood, and is rather soft. The sapwood serves mainly in carrying water from the roots to the leaves. Thousands of cells help in the process, some of them thin-walled living cells called parenchyma (pă rĕn'kĭ-mȧ)—but most of them dead ones.

All of us, at one time or another, have seen the stump of a tree from which the top has been cut. As we looked at the cut surface, we saw that the wood was arranged in rings, one surrounding another. So in all our com-

mon woody stems the wood is formed in rings, usually one ring laid down each year. Because one ring is laid down in each year or growing season, they have been called "annual" or "growth" rings. And they can be seen clearly and counted in most woody stems. In the faster-growing trees, such as poplars, they are harder to separate than they are in trees of slower growth. It is by the counting of these annual rings that the age of some of the older trees has been discovered. Some of the large trees of California show several thousands of growth rings.

Photo by U. S. Forest Service

Some years ago a tiny sapling found foothold in a cleft of this great rock. Now the might of the growing thing has split the rock wide apart.

Just outside the xylem is a single layer of cells which we call the cambium (kăm′-bĭ-ŭm). When we strip off the bark from a woody stem, we usually pull it off at the cambium. And this layer is an important one. You remember that the increase in length of stems is due to a division of cells at the tips of the stem. It is this cambium layer which divides and so increases the thickness of the stem. In this way, fresh cells for conducting materials are formed every year. Toward the inside of the stem, sapwood cells are produced, while toward the outside other conducting cells are formed. Aside from forming new cells, the cambium seems to have no other duties to attend to; it does not seem to transport materials, neither does it support the stem.

Photo by American Museum of Natural History

The days of this fine magnolia tree are numbered. Even if the wielders of the axe never return to cut through the rest of the trunk the tree must die. For it has been deeply "girdled" and the tubes that carry food to the roots and water to the top have been cut. A few swings of an axe can destroy what it took Nature years to build.

Just as the cambium produces sapwood to the inside, so it produces cells to the outside which are called phloëm (flō′ĕm) cells or, commonly, "inner bark." It is in this inner bark that food materials are carried from the leaves down to other parts of the plant. Even though the Indians did not know about inner bark, or cambium, they did know that if they cut a ring around a large tree deep enough to go through the cambium, the tree would die. We, too, often do this, especially with undesirable trees. This is a convenient way to kill a tree, for it prevents food from getting down through the inner bark to the roots and so starves the roots. The roots then die and can no longer absorb water. Then the rest of the plant, left without water, dies too of thirst. For no cell can live without water.

We notice in our oak stem that just outside the inner bark there is a very irregularly arranged layer. It strikes the eye and interests us because it is so rough; and from time to time small pieces of it drop off. This is called the outer bark, and is familiar to us all. If we examine tne outer bark in detail, we find that is is made up of two general types of cells; in

one, the cells are very close together and arranged in rows, while in the other the cells are very irregular. The cells arranged in rows are called cork cells, and it is mainly because of these cells that the bark is important. The cork cells are waterproof—otherwise we could not use corks to keep liquids in bottles. They prevent much water from being lost by the stem of the plant. In addition, cork acts as a very good insulator when the stems are exposed to direct sunlight. It thus prevents the older stems from heating too much and causing an injury commonly called "sun scalding." Many young stems suffer this kind of injury, especially near the surface of the soil, before they have developed cork layers.

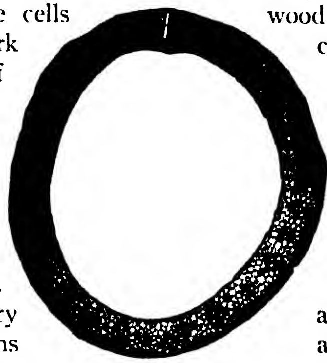


Photo by McGraw-Hill

This is an enlarged cross section of a stem of wheat. You will notice that wheat, like most other grasses, has a hollow stem. The small dark clusters are vascular bundles.

But you may say that you have seen very different kinds of bark from that of the oak, and this is quite true. The Indians noticed years ago that one could strip large pieces of bark from the birch tree and use them for building light canoes. These pieces of bark are made of many layers and protect the tree very nicely. In the shagbark hickory, we notice that very large, irregular pieces of bark are formed which separate from the stem. This kind of bark gives a very rough appearance to the stem, and so makes it easy to recognize. Thus we find that the various kinds of woody plants have their particular kinds of bark.

Photo by Cornelia Clarke

If we could see a common potato plant both above and below ground it would look much like this. There is a green stem with leaves above in the sunlight, and below in the earth grows the swollen, starchy stem which we eat.

In our cross section of the oak stem, undoubtedly all of us have noticed lines radiating from the central part of the stem. These are called xylem or wood rays, and they really consist of ribbon-like sheets of living cells which extend out toward the bark from the center of the tree. They always unite with ray cells that are present in the phloëm. These wood rays seem to serve not only in carrying materials crosswise through the tree, but also in storage. In some woods they are very conspicuous. In oak they are especially large and, partly for that reason, oak is used much in cabinet-making. If the log is cut so that the surfaces of the boards are parallel to these rays they appear as noticeable, smooth markings. Boards so cut are said to be "quarter-sawed," because the logs are quartered so that the cuts will run toward the center and thus show these markings.

There are many other structures in woody stems, though it would take a microscope to find most of them. But there is one set of structures that you can see plainly on most woody stems, whether of trees or shrubs or vines. Perhaps you have seen them best on birch or cherry. They are slight, horizontal elevations on the bark—in birch they are rather dark—usually larger or more conspicuous in spring than in the summer. These are called lenticels (lĕn′tĭ-sĕl)—from the Latin name for a small lens, because in many plants these structures are lens-shaped. Actually they are composed of a great number of cells with much space between the individual cells. It is through these spaces that air can move in and out of the stem.

Another type of common stem is like that of our clover plant or buttercup plant. This is called the herbaceous (hẽr-bā′shŭs) type of stem, for all plants which have little wood are known as "herbs" (ûrb) and their stems are short-lived—as in the clover and buttercup.

How do these stems differ from the woody ones? In the first place, they have a very large pith of parenchyma. Instead of having a continuous cylinder of xylem and phloëm, they have only groups of xylem and phloëm cells which we call "bundles." The number of these bundles varies with different plants, but they are usually arranged in rings. There may be a layer of cambium between the xylem and phloëm, and this cambium may produce a few new cells both toward the inside and the outside of the stem.

Outside of the bundles comes a layer of cells which we call the cortex. In this type of stem, the cortex protects the bundle from injury and really acts as a cushion. The outermost layer of cells is called the epidermis (ĕp′ĭ-dûr′mĭs), and forms a complete covering over the stem. Usually there is a waxy substance, made by these cells, which hardens on the surface. This wax makes a good waterproofing for the stem, very much as paint or varnish acts as a waterproof on our buildings. In fact, the oils and waxes that we use in our paints and varnishes come from plants, and these same materials dry on the surface of the plants themselves, making them partly waterproof.

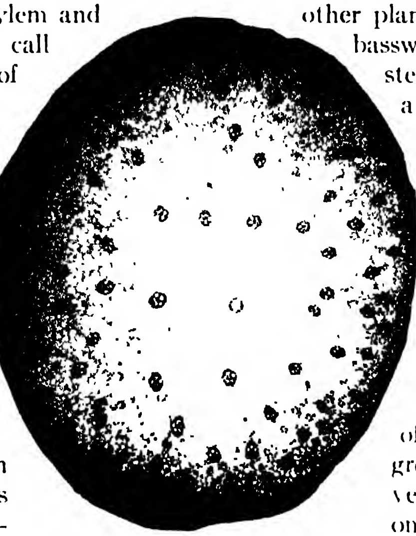


Photo by McGraw-Hill

If you were to cut through a cornstalk between the joints, the cut surface would look much like this. For though corn is one of the grasses, it does not have a hollow stem. Sugar cane is like it in this respect. The small dark clusters are the bundles.

The Third Type of Stem

There is still a third type of stem which we find in such plants as corn, lilies, and orchids. Here again we do not have a solid cylinder of wood and bark, but bundles. These bundles are not arranged in a ring, as in buttercup or clover, but are scattered all the way across the stem, though more abundantly toward the outside. Because these bundles do not possess cambium, the stem does not increase in size as it grows older.

All of the stems so far mentioned are ones that are aërial, that is, they are produced above the ground and exist in the air. Many plants, such as potatoes, for instance, have some stems underground, and from these stems branches are sent into the air. Still other plants, such as the water lily, bassweed, and pondweeds, have stems surrounded by water and are called "aquatics" (ȧ-kwă′tĭk)—which means that they grow in the water. The stems of these aquatic plants usually have large air spaces in them, and for that reason may remain erect in the water or even float. No doubt you have visited ponds or lakes in which some of these plants have been growing, sometimes covering very large areas and floating on the surface of the water.

Ordinarily we think of a stem as being cylindrical when cut across and more or less erect, but there are many modifications. Many of these you would scarcely recognize as stems, and you could be certain of them only by careful study with the microscope. In the Canada thistle, and in many of our common ferns and grasses, the stem is naturally underground and grows parallel to the surface. Occasionally it sends up branches at short distances. Some of the worst weeds that we have to drive from our fields and flower gardens belong to this group.

All of us know that the potato grows underground. The kind of stem it has is called a "tuber," and it is used by the plant to store food. This is fortunate for us, for we also can use this food to keep us alive. The "eyes" of the potato are buds, and when we plant potatoes we must be sure to have at least one eye present, for each eye is able to produce a shoot, and no shoot will arise except from an eye.

How Can an Onion Be a Bud?

And we have still other kinds of stems. The common onion is really a bud—a shortened stem whose leaves have been reduced

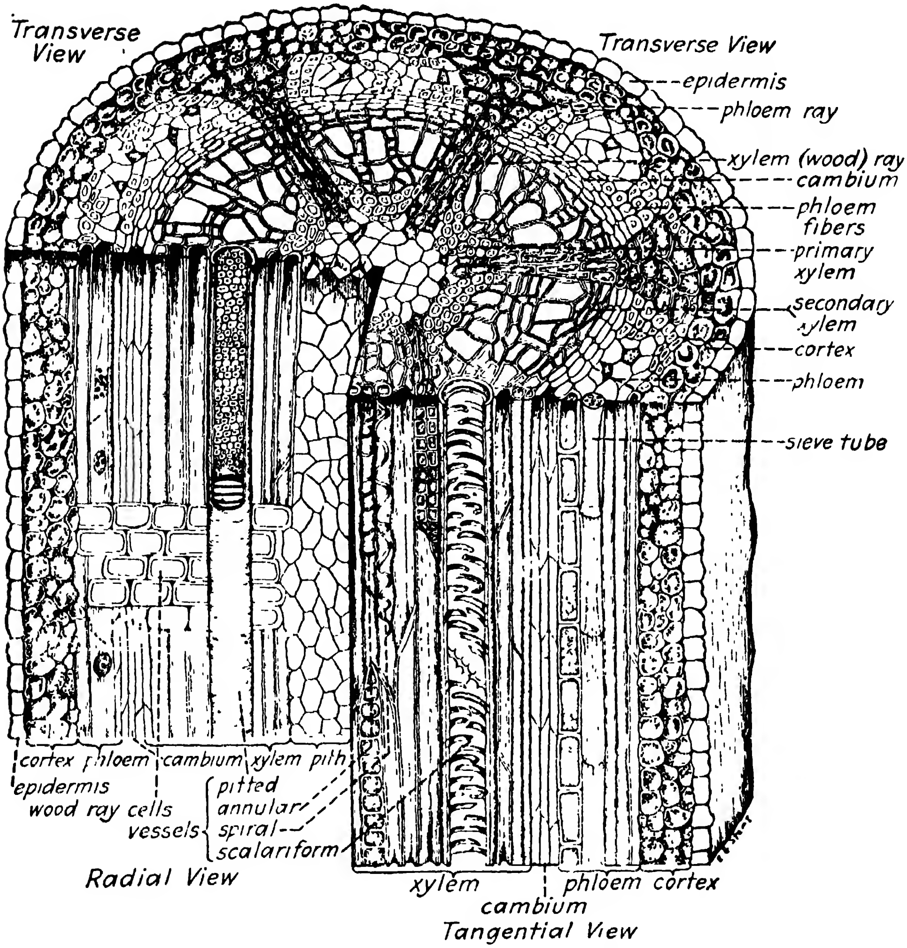


Photo by McGraw-Hill

This picture which is much like a diagram shows the arrangement of the various kinds of cells in the stem of a year-old Liriodendron, or tulip tree. The stem was cut through once crosswise. Next, a lengthwise slice was taken off one side, disclosing the tangential view; and then two lengthwise cuts were made in such a way that the cut surfaces met at right angles at the center of the stem.

to scales. It is called a bulb. Many of our common wild plants which form flowers in the spring have this sort of underground stem. Ginger, ginsing (jĭn′sĭng), sweet flag, and Jerusalem artichoke are either underground stems or are produced by underground stems.

Why Some Plants Have Spines

Most of us have seen or felt the spines on the honey locust or hawthorne. These are modified lateral branches that protect the plant from being injured by animals. In the fox grape, tendrils are very noticeable, and these also are really side branches or stems. Some plants have unusual stem developments to suit the conditions in which they grow. The cacti and other desert plants have few leaves; their stems have taken on some of the functions of leaves. In the cacti the stems are green and manufacture the food for the plant. And in these stems there are many water storage cells. Because of the large amount of water stored in these cells, the plant is able to live through long periods of dry weather when it can get no water from the soil.

Probably most people if asked to point out the part of a plant that seemed the least interesting would choose the stem. Yet it is one of the most important parts, and one of the most amazing.

Reading Unit No. 6

WHAT A PLANT ROOT DOES

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The importance of roots to plants, 2-35-36
Why roots grow toward water, 2-36
How the tips of roots escape injury, 2-36
How roots are formed, 2-38
Roots that live aboveground, 2-38
Roots as food for man, 2-38

Things to Think About

How do roots help a plant?
What do roots take from the soil?
Why are not growing root tips injured by sharp grains of sand?
What tiny structures on roots absorb water and minerals?
In what ways are roots like stems?
Why are some roots very long?
Of what use are aërial roots?

Picture Hunt

How can a banyan tree spread itself over a large area? 2-35
In what part of a root may the vascular bundle be found? 2-36
What may cause an ordinary pine tree to develop into a dwarf tree? 2-37
Why are many roots found aboveground in a mangrove swamp? 2-37
Why must trees be transplanted with a great deal of the original earth? 2-37

Leisure-time Activities

PROJECT NO. 1: Place some grass seed between two wet blotters inclosed between two saucers. When the seeds germinate, watch the development of root hairs on the young roots, 2-36-38.

Summary Statement

Roots do not make food for the plant. They bring it water and minerals from the soil. These materials are used by the plant in food making. Roots also anchor the plants in soil. Some plants use extra roots which act like braces or stilts above the ground. Many of our important foods are roots—for instance, turnips, carrots, beets, and sweet potatoes.

Photo by N. Y Botanical Garden

The banyan tree has roots underground like any other tree, and in addition has a great number of extra, or "adventitious," roots which reach back into the earth from the lower trunk and branches. Of course this arrangement provides stout props for the tree's branches, and therefore the tree may spread them out very far from the main trunk. There is one famous banyan tree in India which has spread out so enormous a canopy of branches that seven thousand men can stand under the shadow of that one amazing tree.

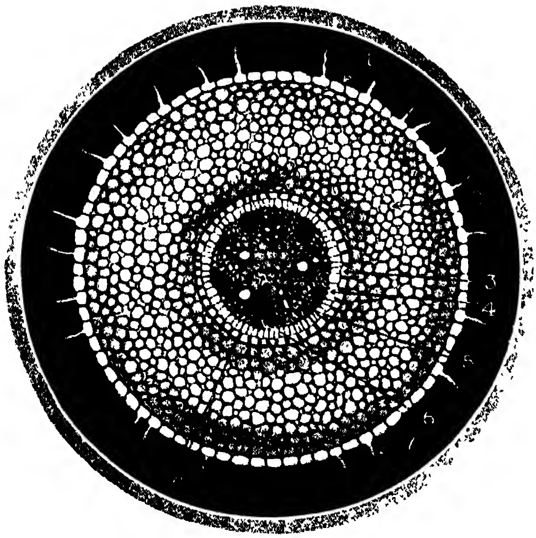
WHAT *a* PLANT ROOT DOES

It Is Not True That Roots Absorb Most of a Plant's Food from the Soil, as Many People Think

ALMOST all plants have roots as well as stems, and it is hard to say which parts are more important. Both are necessary to the plants that have them. Only in rare instances do higher plants have no roots.

It is not hard to see that one of the most important services of roots is to anchor and hold up a plant, for without anchorage even the largest and strongest plant would topple over in a breeze or storm. So the root acts for the plant just as a steel and concrete foundation acts for a skyscraper. This anchorage in the roots is very secure, and it tends to hold the soil particles together. For that reason certain grasses and other plants are planted in sandy places to prevent the sand from being shifted by winds.

When a tree trunk is ringed down to the wood, food cannot get to the roots, and the plant will finally die. In some way the proper action of the root has been interfered with. Roots are usually responsible for all the water and mineral substances that are taken into the plant; and when they are starved they cease to act. Both water and mineral substances are necessary to the life of a plant, just as they are to that of an animal. With few exceptions, all water and mineral substances used by the plant enter it through



Photos by General Biological Supply House

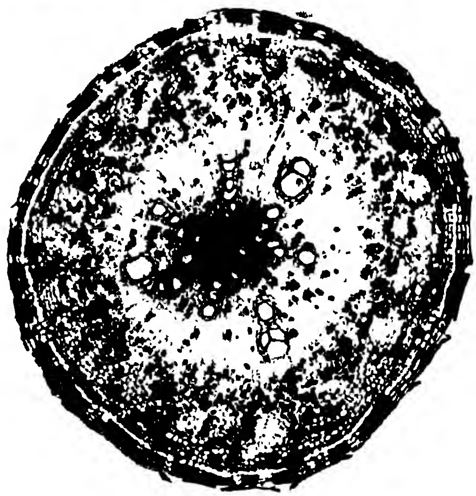
Above is a cross section of a young root, greatly enlarged. In a root the conducting or vascular tissues (8) are in the center, instead of nearer the surface, as in a stem; 4 is the outer layer of the bundle, 5 its wood cells, and 6 a mass of phloëm the part of a stem or root through which materials flow. Outside the bundle is the endodermis, or innermost layer of the cortex (3) and the main body of the cortex (2). Outside that is the epidermis (1) with its tiny root hairs (7). In the picture at the right we see a root tip cut lengthwise. A is the root cap, B the growing point, and C and D further developments of growth. The lowest picture is a cross section of an older root.

the roots. Even shortly after a root is formed and makes its way into the earth, it grows in the direction of water and other necessary substances. For it is necessary that there be a constant flow of these materials from the soil to the stem. It is remarkable how the root will almost invariably grow in the direction of these materials—so much so that Charles Darwin once said that the tip of the root is the nearest thing to a brain that a plant has!

How the Root Tip Is Protected

How is a root fitted to carry on this duty of absorbing necessary substances? It is evident that the tender root tip would be injured if it kept rubbing against soil particles as it grows forward. The soil particles really act as sandpaper upon the root. So the root needs protection, and the protection is supplied by the "root cap." This cap is a thimble-shaped mass of cells a few layers in thickness. As the root pushes and twists on its way through the soil, the outermost layers of the root cap are gradually worn away. They are replaced by new cells, which are constantly being formed beneath. That same growing point which is building cells of the roots also forms cells which become a part of the root cap. The root caps are so small that usually they cannot be seen with the naked eye.

Not far behind the growing point, which is covered by the root cap, we find that the cells are growing in size. It is really here that the actual growth or increase in the length of the root occurs. Soon after the cells of the root have reached their mature size, the outermost layer of cells, or epidermis (ĕp'ĭ-dûr'-mĭs), begins to



develop hairs. These root hairs are so plentiful as to seem as numerous as the little hairs which make up the surface of velvet. It is largely through the root hairs and through the young root between the root hair region and the growing point that a root absorbs the minerals and water. The minerals are dissolved in the soil water,

WHAT A PLANT ROOT DOES

Here is a group of pictures showing various surprising things that roots will do on occasion. In 1 is a pine whose roots have found enough soil between the cracks of a rock to enable it to grow a little, though it remains a mere dwarf. In 2 we see the great buttress roots of a silk cotton tree of Nassau. Though much of the soil on the bank shown in 3 has been washed away, the tree is still able to hold its position by means of the strong roots on the other side. The tree in 4 has found enough earth between the tiles on the roof of a courthouse to let it grow at least for a time. In 5 we see the tangled mass of roots above ground in a mangrove swamp; —hardly the place you would choose for a stroll. The roots of the house plant in 6 have been so crowded that they have come through the hole in the bottom of the pot. In 7 a large tree is being moved; notice how wide a patch of earth has to be cut out in order to get enough of the roots.

just as salt may be dissolved in water. And it is from soil water that the plant gets the food it takes from the ground.

The Short Life of Root Hairs

Root hairs are short-lived. They may last only a few days or weeks. As rapidly as old hairs die or are broken off, new hairs are formed. All the while the root is growing through the soil. Thus the root hair region is constantly being thrust into new and fresh soil, and it never lacks for the service of these absorbing structures.

The inner structure of a root is very much like that of a stem. Let us examine a section of a fairly old oak root. Unlike the stem, no pith is ever present in any root. Occupying the entire center is a core of wood, or xylem (zī'lĕm). This xylem carries water and possibly a small amount of minerals in the same way as in the stem. Surrounding the xylem is the single layer of cambium (kăm'bĭ-ŭm) which forms cells both to the inside and to the outside of the root. The bark—the root of the oak possesses a bark just as does the stem—covers the cambium very snugly and gives it good protection. The inner portion of the bark is very active in carrying food from the stem to the parts of the roots. Not all roots increase in width as the one we have looked at. The roots and stems are usually alike in this respect; if the stem increases in diameter by means of a cambium, then the root usually does.

When a plant first begins to grow, it usually will have only a single root. It is from this root that the root system for the entire plant will be formed. In many kinds of plants, the first, or primary, root may stop growing while the plant is still young. This results in the production of numerous new roots at the base of the stem, of about the same size. Such roots are called fibrous, and they may extend for great distances through the soil. Palms, corn, and wheat possess this kind of root system. Such a system usually becomes extensive and may grow for many feet. Alfalfa roots are often twenty feet long, and a common wild prairie rose has even longer roots. With such long roots, a great number of small rootlets are produced. One oat plant may have so many fine roots that, if placed end to end, they would reach more than four hundred feet.

Sometimes the original primary root grows straight down and becomes much larger than any of its branches. Such a root is called a tap root. Dandelions, radishes, turnips, and carrots have tap roots.

While the roots of our most familiar plants grow in the earth, there are some which are formed in the air, and called aërial (ā-ē'rĭ-ăl) roots. In some tropical air plants—plants which do not take root in the soil—the roots not only serve in fastening the plant to the tree or object upon which it will grow, but will also take in water.

The March of the Mangroves

The mangrove trees along tropical shores have the habit of dropping new roots from their branches. When these roots reach the soil, they become embedded. Finally there are so many new plants produced, all joined together, that a mangrove swamp is formed. Thus, where the water is shallow, the mangroves seem to "march out to sea."

Some plants seem to have to have extra roots to support them. Frequently corn will send out roots from the stem above ground, and these act as braces or props. In the Tropics, some of the plants do the same thing in a bigger way. In the screw pines and the wonderful stilt palm of Brazil, such prop roots actually take the place of the stem or the trunk near the base of the plant. In such plants the trunk, which may be a foot or two in diameter, never reaches the ground. Before it gets there, it spreads out into many stilt roots. Often these roots are tall enough to allow a person to walk under them and also under the trunk of the plant.

Roots sometimes become so changed that you can hardly recognize them. Some plants use them for storage organs. It is for this reason that we value roots such as those of the sweet potato, the beet, the carrot, the turnip, and, in the tropical countries, the yam and the cassava (kă-sä'vȧ), from which tapioca comes. That is why the Indians used to dig the ground nut, and why people in Europe still dig up cheefa.

Reading Unit No. 7

HOW A PLANT GETS ITS FOOD

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The kind of food eaten by a plant, 2–40-41
Our dependence upon plants, 2–41-42
How we discovered that plants make our food, 2–42-43
What goes on in a leaf, 2–44
Why most plants are green, 2–44-45
How plants get carbon dioxide, 2–45-46
Why plants need water, 2–46

Things to Think About

Of what simple materials are all foods made?
What process sets green plants apart from all other living things?
What is the meaning of photosynthesis?
How was it proved that plants do not get everything they need from the soil?
What proportion of a plant has come from the air?
What happens to a plant if its leaves are injured?
Why are leaves often compared with factories?
Of what importance are light, chlorophyll, water, and carbon dioxide to plants?

Picture Hunt

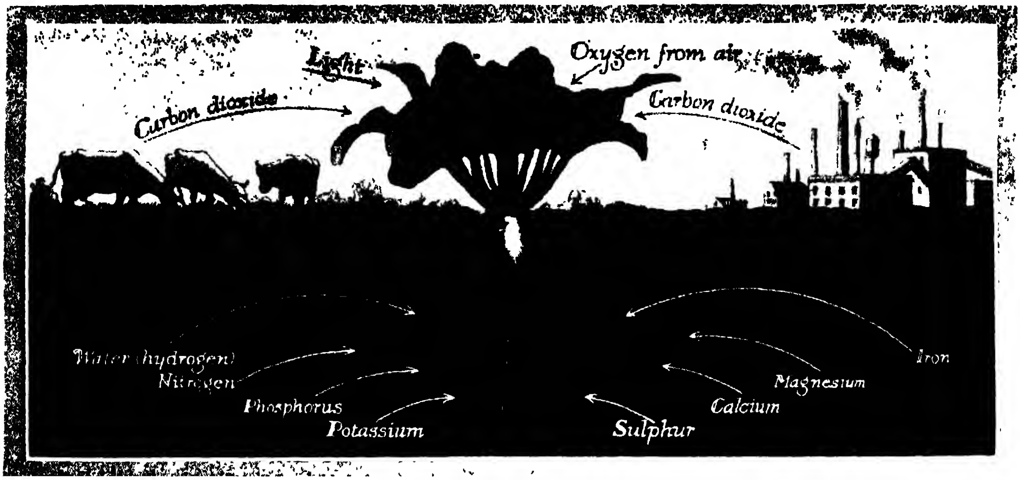
Which part of a plant takes in carbon dioxide? 2–40
What substance made by the leaf is carried away? 2–42
What causes "leaf mosaic" in a plant? 2–43
What may make a plant pale? 2–45

Related Material

How does photosynthesis differ from respiration? 2–49-53
Why are plants said to purify the air? 2–50
Is it safe to sleep in a room with living plants? 2–50

Summary Statement

Photosynthesis is one of the most important of all chemical processes. Green plants, in sunlight, take in water and carbon dioxide and make sugar; they release oxygen as a waste product. The sugar thus made can be turned into proteins and fats by the plant. Animals, including man, depend upon plants for their food supply.



Here is a beet plant, roots and all, pictured in such a way as to show where its food comes from, or rather the source of the simple elements of which its food is made. From the earth, through the roots, comes water, and salts of the needed mineral elements. From the air, through leaves and stem, comes carbon dioxide, given off in the breath of animals, such as the grazing cattle, or by the smoke of factories. It also comes from the soil as a result of the decay of organic matter. Sunlight provides energy for the work of the green parts as they start the complicated process of photosynthesis, which manufactures food for the plant's cells.

HOW *a* PLANT GETS ITS FOOD

Out of the Ground, through the Roots? Mainly Out of the Air, through the Leaves!

ONE of the most important and interesting things about the many plants in the world is the way in which they get their food.

Before telling how a plant gets its food, we had better say first what we mean by "plant food"; for different people think of different things when they use the term. All living things, plants and animals, need certain things to keep them alive and to allow for growth. When we speak of foods for animals we think of "organic" materials, of which there are three very important classes. There are the carbohydrates (kär′bō-hī′drāt), or sugars and starches, which are found in large quantities in such things as potatoes, rice, wheat, or bananas. There are the fats and oils, which are abundant in butter, certain cuts of meat, and in many seeds such as walnuts or coconuts. Then there are the proteins (prō′tē-ĭn), or foods containing nitrogen (nī′trō-jĕn), which are abundant in such materials as meat, eggs, cheese, beans, and peas.

The carbohydrates, or sugars and starches, contain the three chemical elements of carbon, hydrogen (hī′drō-jĕn), and oxygen, and only these three elements. You probably know what these elements are like when pure and not combined with one another. The soot from a smoking lamp is fairly pure carbon, as is also charcoal. Hydrogen when pure is a light gas; and though you cannot see it, you know it as a gas that is put into balloons to make them light. Oxygen is another gas abundant in the air and necessary in our breathing. When hydrogen is burned in oxygen, the two combine and form water. When these three elements are combined in the right proportion they make sugars and starches. Most of the wood in a tree is also a carbohydrate. This is cellulose (sĕl′ū-lōs), which is similar to starch but is not so easily digested; it can be digested to sugar, however, by strong acids. Cotton is one of the purest natural forms of cellulose.

The fats contain these same three elements, carbon, hydrogen and oxygen, but combined

in different proportions from those of the sugars. The proteins also have the same three elements, but in addition they contain nitrogen and sulphur, and often phosphorus. Nitrogen when free and not combined with anything else, is a gas which makes up about eighty per cent of our air. Sulphur when pure and uncombined is a yellow solid or powder which many of you have used in dusting plants to prevent fungous diseases.

What a Plant Feeds On

These carbohydrates, fats, and proteins we think of as foods. In addition to these "organic" foods—so called because they come from animals or plants—animals also require water, which is usually taken in liquid form; oxygen, which is obtained from the air as a gas; and various salts, such as those containing phosphorus (fŏs′fŏr-ŭs) and calcium (kăl′sĭ-ŭm), which are necessary for bone making. Salts of iron, potassium (pō-tăs′ĭ-ŭm), and several other minerals are also necessary. These "inorganic" materials we usually do not class as "foods"; we speak of them as necessary salts or mineral nutrients (nū′trĭ-ĕnt). Now plants require practically the same materials as animals. They require these same sugars, fats, and proteins, just as animals do, and they also require water, oxygen, and mineral salts.

One of the outstanding differences between plants and animals, however, is that many plants have special organs, the green parts, which, under proper conditions, can make sugars out of the raw materials. The raw materials out of which sugars are made are water, which is obtained by the roots from the soil, and carbon dioxide (dī-ŏk′sīd), which passes into the leaf from the air. All other foods are made from these basic foods or sugars.

A Plant's Sugar Factory

The process of making sugars from the raw materials occurs only in the green parts, and only when these are exposed to light and are given the raw materials, carbon dioxide and water. The process is called "photosynthesis" (fō′tō-sĭn′thē-sĭs)—which means "putting together by light"—and it is carried on by the chlorophyll (klō′rō-fĭl), or green coloring matter, that gives the leaves and other green parts their color. The chlorophyll is found in tiny bodies called chloroplasts (klō′rō-plăst).

We must be careful not to confuse this food-making process of photosynthesis with that of respiration, or breathing, in animals. Photosynthesis goes on in the green parts of plants only, and cannot be carried on in parts that lack the green color or in plants that are not green. The process is not to be likened to or confused with the breathing or respiration process which is similar in both plants and animals. The process of genuine respiration or breathing will be discussed in another place in our books.

One can hardly overstate the importance of the food-making process which we call photosynthesis. All living things, plants and animals, are absolutely dependent on it for food. With the possible exception of a few unimportant microscopic forms of plant life, there could be no life on this earth without it, for all living things require these organic foods

Food, Clothes, and Fuel from Plants

Human beings depend on it not only for food but also for many other things. All our clothing made of cotton, wool, leather, silk, rubber, rayon, etc., is produced from materials first made by green leaves. All our fuel, such as wood, coal, oil, gasoline, and gas, comes originally from materials made by green plants. Practically all our power, with the exception of water power and wind, we obtain by burning these materials, which were originally made by plants. Much of our building material, and most of the materials used in commerce, are made directly from plants or are dependent largely on plants for their manufacture. Coal or other materials originally made by plants are necessary even for the making of steel and bricks and concrete.

In addition to these things which the plants make for us, we must not fail to remember that the plants themselves give a great deal of beauty to our homes and gardens, as well as to the fields and woods. They prevent the wearing away of the soil, and are useful to us in an almost endless number of other ways.

This glass model may give us a clearer idea of the process of photosynthesis in a leaf. The epidermis, or outside surface, of the leaf is represented by 8; the opening in 8 stands for a stoma, one of the leaf's pores, by which carbon dioxide and oxygen enter the leaf and both these gases and water leave it. The upright tubes stand for palisade cells containing chloroplasts with their wonder-working green matter, or chlorophyll; the chloroplasts show as tiny dark spots. The air spaces between the cells are marked 5. The curved arrows (1, 2, 3) indicate the passing in and out of gases. The long tube (7) below the palisade cells brings up water; back of the cells is a sieve tube (6), by which the sugars are carried away.

The process of photosynthesis is so important that many studies have been made of it in recent years. Yet it is surprising that only fairly recently has the importance of the process been recognized, even by the botanists themselves.

For many centuries it was thought that plants absorbed all their materials from the soil, that the roots took up everything needed by the plant in its growth, every distinct flavor and substance found in it. Some people even to-day have the hazy notion that plants get everything from the soil. But this is by no means true.

Photo by Chandler Improvement Ass'n

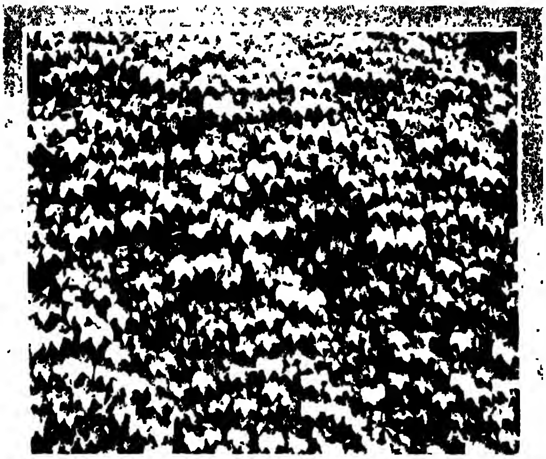
All the fluffy cotton in this field—and hence everything we make of cotton—must get its food, like all fruits and seeds, from the green leaves of the plant.

One of the first known experiments with a bearing on the problem was carried out by a Dutch physician, van Helmont, about the year 1630. Van Helmont took a tub of soil, dried it, and weighed it. In this he placed a willow branch weighing five pounds. He watered the plant regularly with rain water over a period of five years. The branch developed roots and grew until at the end of the five years it weighed 164 pounds. He then dried the soil again and found it had lost only two ounces. Since all he had given the plant had been rain water, he concluded that the plant

lived entirely on water. At that time practically nothing was known about the gases in the air, and his conclusion seemed justified. Now, of course, we know that most of the gain in weight had come from the carbon dioxide of the air through the process of photosynthesis.

In spite of the evidence that the plant had taken water and only a few ounces of other materials from the soil, people still continued to believe that all of the materials came from the soil. Many years later, in the period from about 1775 to about 1804, at a time when more was being learned about the chemistry of gases, it was found that in the light the leaves of plants absorb carbon dioxide and give off oxygen. But it was still not clearly recognized by botanists that this gas exchange was related to food manufacture; that was not clear until about 1865. By that date men had learned that starch or sugar is made in the leaves when they are exposed to light, and that this is an important food-making process.

Even now we do not know so much as we should like to know about the process. We do know, however, that only the green parts of plants can carry it on. We know that carbon dioxide, absorbed from the air, is combined in the green leaf with water to form sugar, and that light energy is necessary to bring about this change. We know also that oxygen is given off as a waste product. We know that all organic matter in nature was first produced by this process, as carried on in green plants. We also know that this food is as necessary to plants as it is to animals, and that without these sugars the plants themselves could not grow.



Photos by Cornelia Clarke and N. Y. Botanical Garden

Most plants like the sunlight to fall directly on their leaves. The picture above shows how Japanese ivy leaves are so arranged as to shade each other scarcely at all; so neatly do these leaves, and others, fit into such an arrangement that we speak of it as "leaf mosaic." The picture below shows how, when the light comes from one side, plants will bend so that the leaf blades may be exposed to it.

Usually nine-tenths or more of the solid matter in a plant is made up of organic matter resulting from the process of photosynthesis. The sugar is produced from the three elements—carbon from the carbon dioxide of the air, hydrogen from water in the soil, and oxygen which may come either from the air or from the water. More than three-fourths of the solid matter of a plant, therefore, has come from the air; and leaving out the water, less than one-tenth has come from the soil.

People working with plants often overlook the fact that all of a plant's food is made in the green parts, and that only a small though very important part of the solid material comes from the soil. Of course, we must not forget the materials that come from the soil, such as the nitrogen, phosphorus, and potassium; but all the same we must remember that practically all the food

for the plants is made in the green parts. This is why removal or killing of the leaves by insects, by plant diseases, or by too much pruning, prevents the growth of roots, of tubers, or of fruits. Since the leaves make nine-tenths or more of the materials that are used as food in forming shoots, roots, tubers, and fruits, and since these other parts cannot make their own food or get it from the soil, it is clear that if the leaves are destroyed, these other parts cannot get enough food and will have little or no growth. If you want your grapes and tomatoes to ripen and fill with sugar, do not cut off the leaves. If you want big potato tubers or beet roots, do not let insects or fungi destroy the leaves that make food.

Since photosynthesis is so important, we ought to know what conditions are necessary for the leaf to make sugar. We ought to know how fast leaves can make this sugar, how different conditions affect the rate at which the food is made, and how these conditions may be changed to make the rate faster or slower.

What Goes On in a Plant's Sugar Factory

When a leaf carries on a process like this one of photosynthesis, for which many different things are necessary, we cannot always predict just what will happen when one of the conditions is changed. For example, light is absolutely necessary to supply the energy or power to make the sugars. In darkness no photosynthesis whatever can take place. If the light intensity is gradually increased the rate of sugar manufacture will increase—but not indefinitely. On a cloudless day in summer probably most plants do not make any more sugar—possibly they make even less—than they would make if the light were only half as strong. In full sunlight, therefore, the leaf has more light than it can use, and the rate cannot increase because something else is lacking. Perhaps there is not enough raw material, such as carbon dioxide.

One might compare this process of food manufacture with some commercial process, such as that of making boxes. For such a process one must have the raw materials, the lumber and nails; there must be the saws and other machines for preparing the lumber; there must be the power to run the machines for cutting and preparing the boards; and there must be workmen to direct the power and handle the materials. In this process of food manufacture we may compare the raw materials, the carbon dioxide and water, with the lumber and nails; the green coloring matter, chlorophyll, with the machines or saws; and the living protoplasm (prō′tō-plăz′m) of the cell with the workmen directing and controlling the process and its products. Now if there is not enough of the raw material, carbon dioxide, for the process, no matter how much water or other raw material there is, no matter how much light or power there is, no matter how much chlorophyll or machinery there is, and no matter how many living cells or workmen there are, the process cannot increase beyond the limit set by the rate at which this one raw material, carbon dioxide, is supplied. And on the other hand, if there is not enough light or power reaching the leaf, no matter how much we have of the other necessary things, the rate is limited by the amount of light

In a process for which several things are necessary, the lack or shortage of any one will not permit the speeding up of the process by adding to the others. This deficient condition we call the "limiting factor." In a process like photosynthesis, therefore, any one of the necessary conditions may become deficient and act as a limiting factor.

Why Most Plants Are Green

We shall consider some of these factors briefly. Take for example the green coloring matter, chlorophyll, which we have compared with the machinery in a factory. Those parts of plants that do not have this green color cannot carry on the process. The white or yellow parts that are present in the leaves of some kinds of plants cannot make food, and those plants that have some of their leaves or parts of leaves lacking in this green color are usually harder to grow than the fully green ones, because the white parts use food but cannot make any. The green parts of these variegated plants have to supply the food not only for the roots,

stems, and flowers, as in ordinary plants, but also for these white parts that give nothing in return.

Usually we cannot control in any practical way the amount of chlorophyll in the leaf; we can do almost nothing about this necessary condition. In some soils, however, especially in alkaline soils or sandy soils with a high lime content and low organic matter, the plants lack the green chlorophyll because in such soils iron or manganese (măn′ga-nēs′) is often lacking, and both iron and manganese are necessary for the formation of the green color. Such plants can often be helped by spraying the leaves with a weak iron solution. Magnesium (măg-nē′zhĭ-ŭm) is another element which is necessary for chlorophyll, but it is only rarely that the soil has not enough magnesium. Nitrogen also is a necessary element, and plants growing in soils without enough nitrogen often show the yellowish appearance due to a low amount of the green color. By the use of proper fertilizers, especially nitrogen, one not only makes the leaves green with more chlorophyll, but he also makes the leaves and the whole plant grow larger. Then the leaves can expose a greater area to absorb light and carbon dioxide for making sugar.

Photo by N Y Botanical Garden

The thin, sickly jack-in-the-pulpit at the left grew in the dark; its healthy brothers at the right grew naturally in the light. A plant like a jack-in-the-pulpit, which has a stem full of stored food, can grow in the dark as long as its food lasts; but it will be sickly and colorless, for it needs light not only for photosynthesis but for the very formation of its green chlorophyll. We have all seen how sickly and pale the grass is under a board that has lain a long time in one spot on the turf.

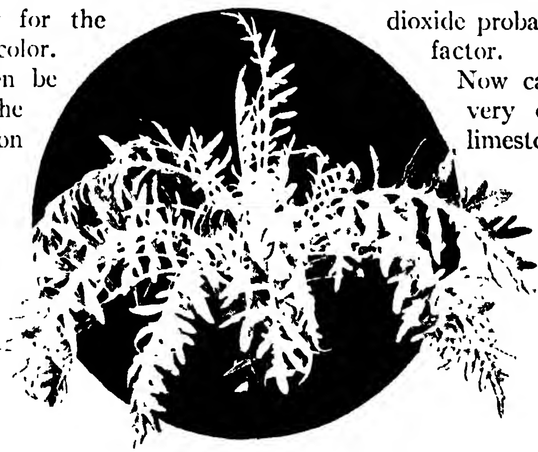


Photo by Cornelia Clarke

The dusty miller plant has gray-green leaves that look as though they were covered with powder. It is only one of the plants with dusty or cottony-looking leaves. The effect comes from the reflection of light from a covering of tiny colorless hairs. This may be of importance to plants growing in intense light because there is danger that strong light will overheat or otherwise injure the leaf.

Carbon dioxide, which is one of the two raw materials out of which the sugar is made, is absorbed from the air as a gas. Now the usual amount of this gas in the air is very small, only about 3 parts in 10,000 parts of air. Oxygen, on the other hand, is present in about 2,000 parts in 10,000, or there is nearly 700 times as much. In spite of the small amount of carbon dioxide in the air, it is from the air that the leaves must get all their carbon for food manufacture. On warm, cloudless days this small amount of carbon dioxide probably acts as a limiting factor.

Now carbon dioxide can be very easily obtained from limestone by treating the stone with strong acids; or it can be obtained as a waste product from the burning of wood, coal, oil, and similar materials. Every ton of wood on complete burning will produce nearly a ton and a half of carbon dioxide, for carbon in the wood combines with oxygen in the air. A ton of coal may produce nearly three tons of carbon dioxide. This would be enough to double the normal amount of carbon dioxide in the air for a depth of five feet over an area of nearly a square mile; and, on a bright day, it ought nearly to double the amount of food made. Since every ton of carbon dioxide would make

about two-thirds of a ton of sugar, the carbon dioxide produced in burning one ton of high-grade coal should make about two tons of sugar or ten tons of living plant tissue such as corn.

So it would seem as if a good part of all the carbon dioxide given off from our stoves and furnaces might be used to help in growing plants. And it has indeed been found possible to increase the rate of growth and food-making in this way, though only in laboratories and greenhouses. Out of doors the wind carries the carbon dioxide away so fast that we cannot as yet make much use of it. In using waste gases from furnaces there is also the danger of injury to a plant from the poisonous gases that are mixed with them. It is the poisonous gases that kill the vegetation near large cities, but these poisons can be fairly easily removed from the air.

Why a Plant Needs Water

Water is another raw material that is necessary for food manufacture. By far the greater part of the water absorbed by a plant is evaporated into the air and lost. A small part, however, is combined with the carbon dioxide to make sugar. When a plant has not enough water, and evaporation is rapid, the plant shows wilting. Even a rather badly wilted plant still has a good deal of water in its cells, probably plenty for photosynthesis; but when the plant has lost a great part of its water, the little pores through which the water passes out of the leaf are closed. Since the carbon dioxide used by the leaf enters through these same pores, the closing of them results in a decrease of carbon dioxide absorption and of photosynthesis.

There are several other reasons why a plant with too little water does not make sugar rapidly. One of these is that without enough water, growth is checked, and the plant does not use up its sugar so fast as it is made. This checks the removal of the sugar from the leaf, which in turn slows up the process. It is very much as if the manufactured products in a factory were not taken away from around the machines, but were allowed to accumulate and interfere with further manufacture.

Of course a plant cannot make any food without light. If the light is very weak, the plant may not make enough food to grow or even to keep alive. Only a few kinds of slow-growing plants can grow in dense shade. In cloudy or rainy weather plants cannot make sugar so fast as they use it; so what they have stored may be used up and the plants may grow weak and watery if the rainy weather lasts too long. The slow speed of growth under insufficient light is very noticeable in greenhouses in the winter. In fact, it has been found possible to help greenhouse plants by the use of artificial light, for plants are not limited to the use of sunlight. They can use many kinds of light. We all know that if light is passed through a prism it is separated into different colors, ranging from red to violet. Now it has been found that plants can use red or blue or in fact any visible color except green. They can use little or none of the green because their own green chlorophyll does not absorb this color.

Reading Unit No. 8

WHAT HAPPENS IN LEAVES?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How the air is purified by plants, 2-49-50
How plants breathe, 2-50-51
The amount of water given off by plants, 2-51-52
How leaves give off water, 2-52
How leaves change starch to sugar, 2-53
Where starch is stored in a tree, 2-53
Where digestion takes place in a plant, 2-53

Things to Think About

What gas necessary for breathing is made by a green plant?
How does respiration differ from photosynthesis?
How is it possible for apples to suffocate?
How do living things get their energy?
How do plants regulate the quantity of water lost from their leaves?
How is the starch in a plant made ready for the plant's use?

Picture Hunt

What did Priestley discover? 2-50
How much water is transpired from the apple tree in twelve hours? 2-51
In what part of a leaf are stomata found? 2-52
Where do leaves get water? 2-48

Related Material

What kinds of plants cannot make their own food? 2-55
What plants make their own food but also add meat to their diet? 2-60

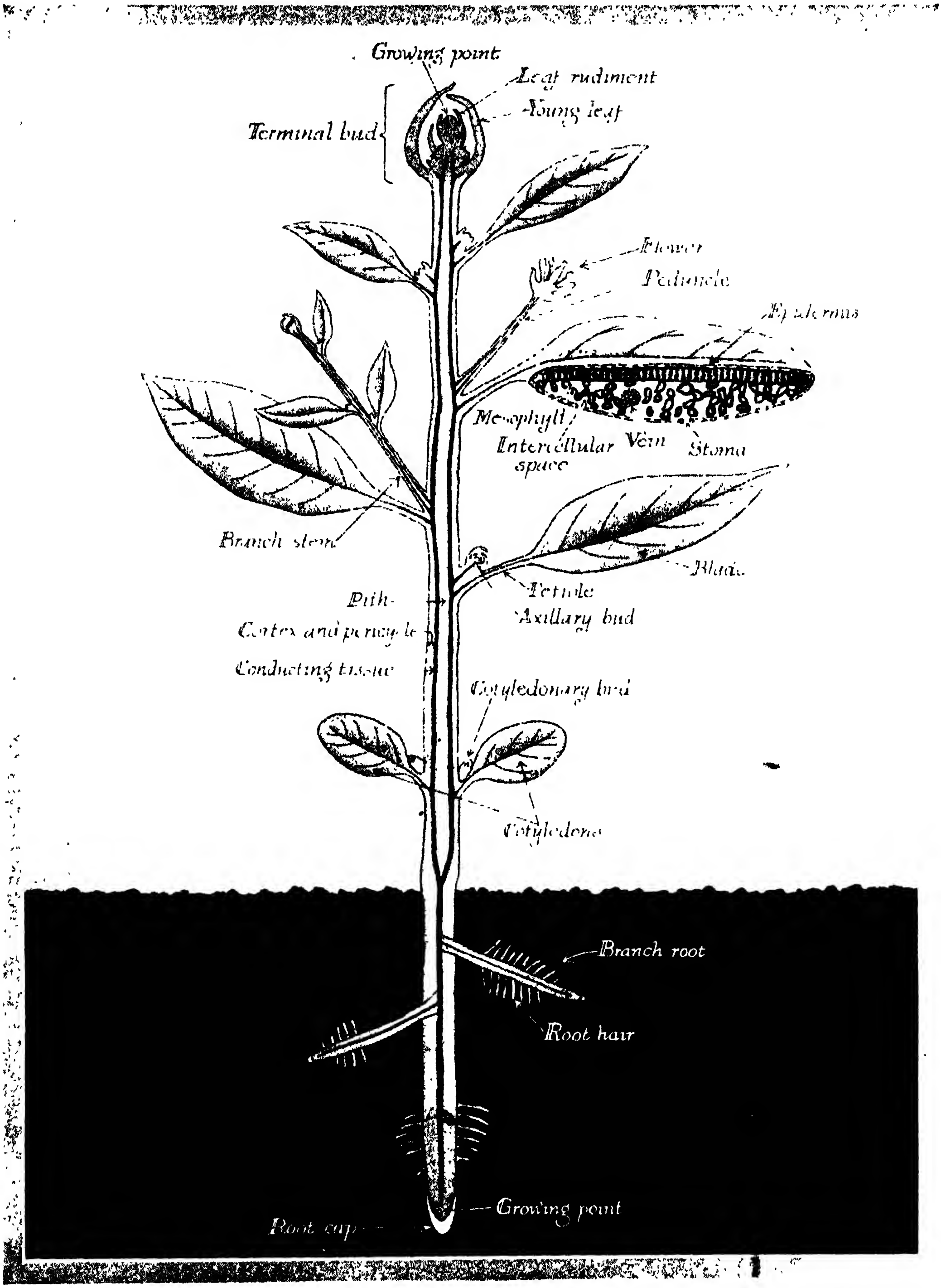
Leisure-time Activities

PROJECT NO. 1: Repeat Priestley's experiment. "Impure" air will not let a match burn in it; pure air will, 2-49.

PROJECT NO. 2: To study transpiration, pour melted paraffin on the soil of a potted geranium. Place the plant under a bell jar. Note the water given off during 24 hours, 2-51.

Summary Statement

Plants breathe just as animals do. They take in oxygen, which unites with food and releases energy. Water and carbon dioxide are waste products and are thrown off. In photosynthesis, plants take in carbon dioxide and water, and, using the energy of light, make food and oxygen.



This diagram shows the parts of a young seedling plant. The heavy black line that runs through the center of the root, then branches out in the stem and sends connections into each leaf and bud and branch, is vascular or conducting tissue; this vascular system carries to all parts of the plant water and salts from the root, and also food made in the leaves. What can you tell about the functions of the other parts of the plant? The section of the leaf at the right is greatly magnified and out of proportion to its other half.

Photo by Cornelia Clarke

Did you know that all these little pansy plants, and all plants everywhere, have to breathe, much as we do? Of course they do not do it in just the same way, but they breathe the same air. They even have to have oxygen, just as we do, and can be smothered by the lack of it. At the same time they carry on, in their green parts, a marvelous process called photosynthesis, by which they take not oxygen but carbon dioxide out of the air. This is not really breathing, though you will sometimes hear it called that.

WHAT HAPPENS *in* LEAVES?

If You Strip a Plant of Its Leaves, What Happens? The Answer to That Question Will Tell What the Leaves of Plants Do

IN TWO preceding talks about botany we have told you all about the importance of the food-manufacturing process which is called "photosynthesis" (fō′-tō-sĭn′thē-sĭs) and which takes place only in the green parts of plants, the leaves. You will remember that it is these leaves that make all the organic material for all plants and animals, and that nine-tenths or more of the solid material in plants consists of this organic material which was first made in the leaves. Although, from the standpoint of men and other living things, the process of photosynthesis is the most important one carried on by the leaves, it is not the only thing they do. All of you know that, while making these foods, there is a gas exchange between the leaf and the air. Carbon dioxide is absorbed from the air and oxygen is given off.

In fact, this gas exchange was observed before people knew anything about the food manufacture. A man named Joseph Priestley, an English clergyman—who, by the way, was mobbed and driven out of England because of some of his advanced ideas, and finally settled in Pennsylvania—was the first to discover and separate the gas oxygen. He found in 1771 that if plants were placed under a glass jar in which the air had been made impure by the breathing of animals, the air would become pure again so that animals could live in it. This led eventually to his discovery of oxygen, but he did not understand the nature of this gas nor did he call it oxygen. He had no idea of what use

the gas exchange is to the plants, and did not realize, as we do now, that it is closely connected with the process of food manufacture. In fact, he and others became confused, because the plants sometimes purified the air and sometimes made it impure, as do animals. You see he failed to recognize what we now know; that is, that light is necessary for the process.

A few years later it was found that in light the green parts of plants purify the air while in darkness they make it impure. In other words, in light carbon dioxide is taken in and oxygen given off, while in darkness oxygen is taken in and carbon dioxide given off. The taking in of one gas and the giving off of another—processes associated with sugar manufacture in green leaves—is often spoken of as the breathing of plants, and there is a widespread notion that plants in their breathing absorb carbon dioxide and give off oxygen, while animals in their breathing absorb oxygen and give off carbon dioxide. This, however, is not true. The two processes are at bottom quite distinct. Plants have a process exactly to be compared with the process in animals in which there is an absorption of oxygen and a giving off of carbon dioxide. This occurs in all living parts of plants. In the leaves, however, there is a totally different and independent process of food manufacture, which goes on only in light and only in those parts that have the green color. In light this process of photosynthesis goes on much faster than the one of breathing, or respiration; so that during the day oxygen is given off from the leaves faster than it is absorbed.

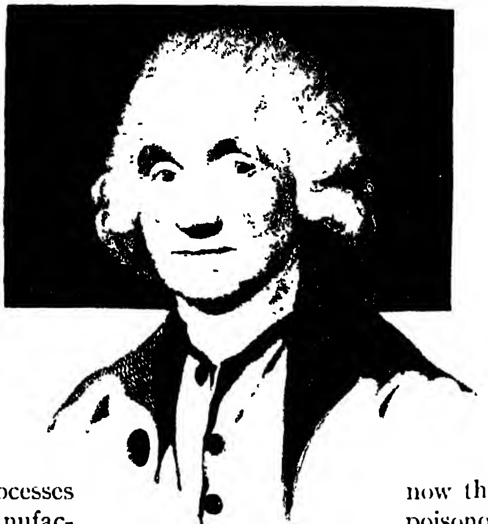


Photo by the Science Museum

This is Joseph Priestley, the man who discovered that plants give out certain gases into the air. You may read of his interesting life elsewhere in these books.

Do Plants Make the Night Air Impure?

The leaves absorb oxygen and give off carbon dioxide at night; and the other parts of a plant, such as fruits, shoots, and roots, do so at all times, night and day. It is interesting to read the account of the discovery of this fact—the fact that green leaves have two kinds of gas exchange, one in the daytime and another at night. In 1779 a man by the name of Ingen Housz, who was the first to discover the fact, warned people against having plants of any kind in the house at night because the plants made the air impure. He also warned people against sleeping under trees, and suggested that cases of sudden death which doctors could not explain might have been due to the fact that plants at night absorb oxygen and give off carbon dioxide. He was right about the gas exchange, but we know now that carbon dioxide is not poisonous, as he thought it was, and we also know that the amount of carbon dioxide given off by plants at night certainly is not enough to damage the air in rooms. So you need not worry about having plants in the house. An extra person in the room, or a dog, will use up much more oxygen and give off more carbon dioxide than a few plants.

But if you shut yourself up tightly in a small room filled with living plant tissues, such as apples or potatoes or moist grain, there may be some danger of suffocation, especially if the temperature is high. In fact, when apples, lettuce, potatoes, and such plant materials spoil in storage or during shipment in railway cars, it is frequently due to suffocation of the plants themselves. They have not had enough ventilation to supply the oxygen they need, or to remove the carbon dioxide which they produce in their process of respiration. Hundreds of carloads of potatoes and other vegetables have had to be thrown out when they reached market because of this spoilage resulting from poor ventilation.

This process of respiration, or breathing,

Photo by American Museum of Natural History

Besides giving off carbon dioxide in darkness and oxygen in light, the leaves of a plant evaporate, or transpire, large quantities of water, as you may judge from the statement on the water tank in the picture. Of course, such large quantities are transpired only when the tree is in full leaf, and not when it is in full bloom as shown in the picture. This water passes out of the leaves mostly through the stomata, which, as you know, are pores in the epidermis, or skin, of the leaf.

in plant cells, we must remember, is almost exactly the same as that carried on by animals, and for the most part it has the same purpose in both plants and animals. Oxygen is absorbed by the living cell. This combines with the sugar, making carbon dioxide and water. This combination of oxygen with sugar, which is similar to burning the sugar, releases the energy that was stored when the sugar was made in the light by the process of photosynthesis. The energy thus released by burning may be used in various ways by the plant or animal. Some is used in manufacturing new living material, thus making growth possible. This is perhaps the most important purpose for breathing in both plants and animals. Some may be used in physical processes, such as muscular activity in animals. Plants do not use much energy in this physical way. Some of the energy may take the form of heat. In warm-blooded animals this is very important. In cold-blooded animals and in most plants, however, it is of little or no importance. The heating of moist grain or hay, however, results from this process of respiration.

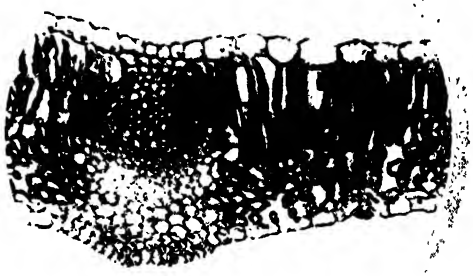
The leaves therefore carry on two processes associated with which there are gas exchanges. One is a food-manufacturing process that goes on only in the light and only in the green parts. Another is an entirely distinct process which is to be compared to our respiration or breathing, in which oxygen is absorbed and carbon dioxide is given off. This is going on in all parts of plants at all times.

How Much Water Does a Plant Give Off?

There is still another process that takes place in leaves. All of you know that plants take a great deal of water from the soil. A small amount of this water is used in making sugar by photosynthesis, but the greater part is evaporated from the leaves and lost. For every pound of water used in making sugar, usually from two hundred to a thousand pounds are evaporated from the leaves. It is really remarkable how much water plants will evaporate, or "transpire," as it is called. Measurements have shown that a single corn plant may lose from two to four quarts of water a day. It has been estimated that an acre of apple trees may lose six hundred tons of water in a season, while a recent calculation shows that on a hot day a good-sized apple tree may lose as much as a gallon of

water a minute. Those of you who have tried to keep house plants moist, or have watered your plants during dry weather, can appreciate this.

It used to be thought that plants had to absorb and evaporate large quantities of water in order to take in enough of the weak soil solution to get from the soil the mineral salts necessary for growth, but recent experiments have shown that plants do not have to evaporate water in order to get these mineral salts. In fact, we have found that this loss of water by leaves probably does little or no good to the plant and often does a great deal of harm. We all know that when the plant has not enough water its growth and yield are reduced, and not a season goes by without plants suffering more or less for lack of water. This is especially evident during periods of summer drought.



Photos by General Biological Supply House

Above is the cross section of the blade of a leaf. The long, dark cells contain green coloring matter, and the smaller cells form the vascular tissue. Below is the surface of a leaf—the epidermis—as one looks down on it. The pairs of dark, crescent-shaped cells are guard cells, and the clear slit between them is the pore. These pores with their guard cells are called stomata. Both views are greatly magnified.

You may wonder why a plant evaporates so much water if the loss is harmful and does it no good. We must remember that the plant has to have a large leaf surface to absorb the light and the carbon dioxide for sugar manufacture. There must also be openings in the leaves to let in this gas and to let out the oxygen. Light can pass through the transparent skin, but these gases cannot. The cells of the leaf also have to have water to keep them alive and to make sugar. With such an arrangement of wet cells inside, and with holes through the epidermis (ĕp′ĭ-dûr′-mĭs), or skin, of the leaf that let in carbon dioxide, the plant cannot help losing some water by evaporation into the air. In fact, most plants have what are called "guard cells" that are capable of closing these pores when the plant loses too much water. Of course when these pores are closed, the leaves cannot continue to make food, for the necessary raw material, carbon dioxide, cannot then get into the leaf. This is one of the reasons why plants do so poorly when they do not have enough water to keep the pores open; under such conditions the leaves cannot continue to get carbon dioxide to make food.

Perhaps most of you have not seen these little pores in the leaf. They are too small to be seen except under a magnifying glass or microscope. It is surprising what a large number of these pores are found on a leaf. Maple leaves have about 194,000 for every square inch of surface. This would mean about 1,700 on an area equal to the cross section of the lead in an ordinary lead pencil. In other words, if you took the lead out of an ordinary pencil, broke it square across, and pressed it on the under side of such a leaf, you would be covering about 1,700 of these little openings; and yet these pores are so tiny, and so far apart on the leaf, that in the same space under the lead there would be room for about 170,000 more pores of the same size.

These little pores are very efficient in allowing for the gas exchange in the food-

manufacturing process. They also allow for the gas exchange in the totally distinct process of respiration, which is like the respiration or breathing in animals. Though food manufacture takes place only in green leaves, the respiration process is carried on by all parts of a plant, and all these parts, roots and all, absorb oxygen and give off carbon dioxide directly. These parts do not get their gas through the leaves; for the leaves do not act as the lungs of the plant, as some people say. The other parts do, however, get all their food from the leaves. It is through these same pores in the leaves that most of the water is lost.

Does a Plant Digest Its Food?

There is still another process that takes place in living leaves; it is one which we call digestion. All of you know something about digestion. For example, starch, which is one of the commonest plant and animal foods, cannot be absorbed by living cells because it does not dissolve completely in water, but remains in solid grains or, if cooked, forms a jellylike mass. Even if it were inside the cell, it could not be directly used. It first must be chemically broken down to sugar, which will dissolve in water and can move into cells and be used by them as food.

In animals or men, who have to get all their food from outside, substances called "enzymes" (ĕn′zīm) are produced by special organs such as the saliva glands, and these enzymes become mixed with the food when we chew it or when it passes through the digestive tract. These enzymes digest the foods, making them soluble—or capable of being dissolved—and thus able to pass into living cells and be used by the cells.

Cells That Make, Store, and Digest Food

Now, unlike the higher animals, most plants do not have any special digestive organs. The food made in the leaves is usually stored as starch in the same cells that make it. When the food moves out to other parts of the plant, it is first digested by an enzyme that changes it to sugar. This enzyme is produced in the cell that stores the starch. Some people say that the leaf is the digestive organ of the plant. This is not so. The plant has no special digestive organs. Nearly all the cells of the entire plant are capable of forming enzymes and digesting foods stored in them.

In an apple tree, for instance, starch is stored in the living cells of the twig, in the bark, pith, and wood. There is also starch stored in the branches, trunk, and roots. Toward spring this food is digested by the cells that store it, and the sugar is used in making new shoots, leaves, trunk, and roots. The starch stored in potato tubers and in seeds of corn and beans is digested in these organs when the plant begins to grow.

Some kinds of plants, such as bacteria and fungi, which cannot make their own food, must depend on that made by green plants. They secrete enzymes much as do animals, and get their food from outside. The rotting of leaves or of the heartwood of a tree is largely brought about by fungi (fŭn′jī) that secrete enzymes which digest the wood, changing it to sugar that is used as food.

What Goes On in a Leaf?

In this story we have read about four different kinds of processes that are carried out in the leaves. One of these, photosynthesis, is carried on by the green parts only. This is an extremely important process, useful to all living things because all the foods used by plants and animals are made by this process. Another process, water loss, which is called "transpiration," is carried on mostly by leaves; though there is some water loss by other parts if they are exposed to dry air. This water loss is of little or no use to the plant and is a source of great danger to it. Another process, respiration, which is similar to the respiration of animals, occurs in all living cells and is not restricted to the leaves. This process is important in releasing energy for growth and for other reasons.

The last process we have read about is digestion. This in plants is not restricted to the leaves or any special organ, but may occur in any living cell. It has the same function in plants as in animals—that of making the foods more soluble and available.

BOTANY

Reading Unit
No. 9

SOME PLANTS THAT STEAL THEIR FOOD

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How fungi steal their food 2–55
How the mistletoe harms its host, 2–56
How parasite plants get their food, 2–56
How some parasites enrich the soil, 2–58

Things to Think About

How can you tell if a plant is self-supporting?
Why is a plant parasite bound to harm its host?
Why are saprophytes very important to all living things?
Why is dodder a great danger to the farmer?
In what way are members of the pea family helped by parasites?
How do lichens illustrate symbiosis?

Picture Hunt

Why are mushrooms called saprophytes? 2–55
Where does mistletoe grow? 2–56
What parasite is starving the daisy? 2–57
What plant is breaking up the dead tree stump? 2–57
How is the lichen less simple than it looks? 2–58

Related Material

Of what use are bacteria to plants like beans and peas? 2–168
Can we make lichens artificially? 2–80

Leisure-time Activities

PROJECT NO. 1: To find chlorophyll in red leaves, boil out the red color of leaves of coleus, and of red beech and barberry, 2–55.

PROJECT NO. 2: To find the parasites which help legumes, pull up the roots of clover and look for the nodules on the roots, 2–58.

Summary Statement

Only green plants can make their own food. Those lacking chlorophyll must get their food ready made. A plant that takes its food from the organism on which it grows is called a parasite. A plant which gets its food from a dead organism is called a saprophyte. Sometimes two plants live together for mutual benefit, as in symbiosis. The lichens, for example, consist of algae and fungi. The fungus absorbs water and minerals, while the alga makes food.

Those very interesting plants that we call mushrooms and toadstools are saprophytes; that is, they draw their food from other plants which are decaying in the soil. They themselves have no green chlorophyll with which to make their own food.

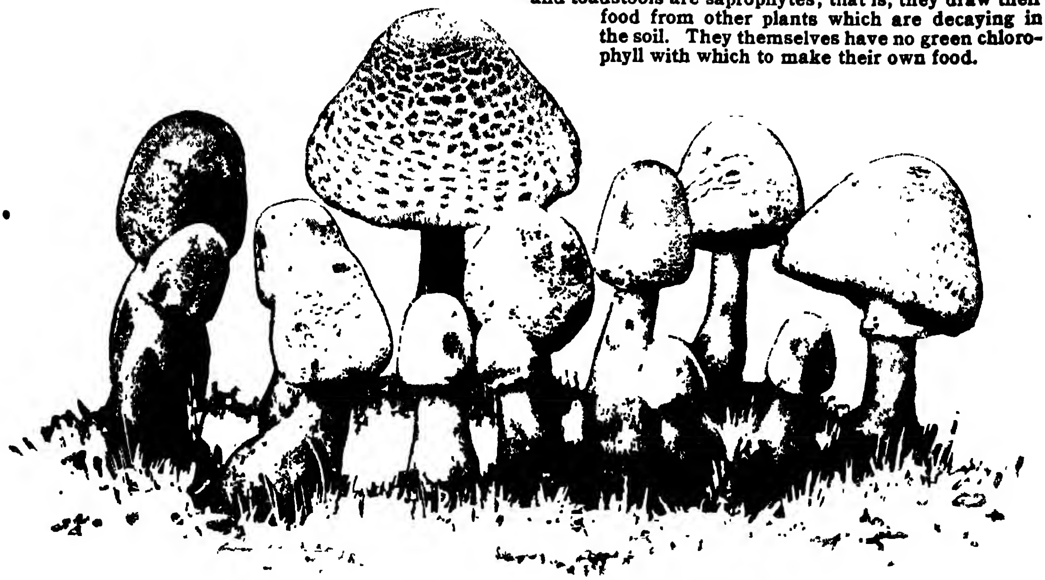


Photo by Cornelia Clarke

SOME PLANTS THAT STEAL THEIR FOOD

Unable to Make Their Own Food, as Green Plants Do, They Live on What Others Have Made

MOST of the flowering plants make their own food. They support themselves. But there are some that get their food in other ways. Some of them steal their food from other plants, and some use what the other plants have discarded.

The easiest way to tell whether a plant is self-supporting is simply to look at its color. If it is green, you can be fairly sure that it is self-supporting. The green color is the sign that tells you the plant can make its own sugar and starch from carbon dioxide gas, and water. If it has no green leaves or green stems, but is white or yellow or brownish, you can be fairly sure that it ~~is not~~ self-supporting.

Sometimes the green sign does not show. Some plants, such as iresine (ī′rē-sī′nē), certain varieties of coleus (kō′lē-ŭs), and the bronze-leaved varieties of beech and barberry, have red or purple leaves. These colors merely hide the green, however; if the leaves are boiled in water, the red or purple color will come out, and the green, which does not dissolve in water, will be left in the leaf, where it can be easily seen. There are also a few yellow-leaved varieties of plants like coleus, elderberry, and elm, which are grown because of their peculiar color. Although these varieties do not look very green, they do have some of the green chlorophyll (klō′rô-fĭl) in their leaves and are not completely yellow.

There are many kinds of plants, however, that are not green. Such plants cannot make their own food. Most of the plants that are not self-supporting are not flowering plants, but belong chiefly to two large groups, the fungi (fŭn′jī) and bacteria (băk-tē′rĭ-ȧ), which you can read about elsewhere in our books. Many of these get their food from living plants or animals. These are called "parasites" (păr′ȧ-sīt). "Parasite" comes from two old Greek words which mean "one who eats at the table of another." These parasites do more or less harm to their hosts, and often cause serious diseases and even kill their hosts.

SOME PLANTS THAT STEAL THEIR FOOD

Some of the plants that are not self-supporting get their food from plants or animals that are no longer living. They get their food from dead leaves, stems, trunks, and such materials. These plants that get their food from such dead materials are called "saprophytes" (săp′rô-fīt). They cause the rotting of the dead materials by secreting enzymes (ĕn′zīm), substances which digest the wood and the leaves, making them available as food.

Photo by H. E. Zimmerman

Christmas decorations are not quite complete without a sprig of mistletoe, and many are the legends and superstitions about this little plant. Yet it is a partial parasite, living on trees, such as the oak in this picture.

Both of these groups, the fungi and the bacteria, are considered as lower organisms in the plant kingdom. They do not have flowers or stems or leaves. But among the so-called higher plants, the flowering and seed-forming plants, there are also some kinds that cannot make their own food, but behave as parasites or saprophytes. Some of these are wholly dependent on their hosts, while others are partly dependent. Those that are partly so are often called "partial parasites." Such are the mistletoe and many plants in the figwort family. They take water, mineral salts, and part of their food directly from the sap of other plants to which they are fastened. They look somewhat like ordinary green plants, and they do the same things with the green coloring matter in their leaves; but they steal all their water and salts, and probably part of their food, from their "host plant." In the plant world a host never invites his guests, but he often has to support them when they come to steal a good part of his food. Some of these partial parasites are very beautiful—such as the purple gerardia (jē-rär′dĭ-ȧ), the rattle, the handsome scarlet painted cup, and many others.

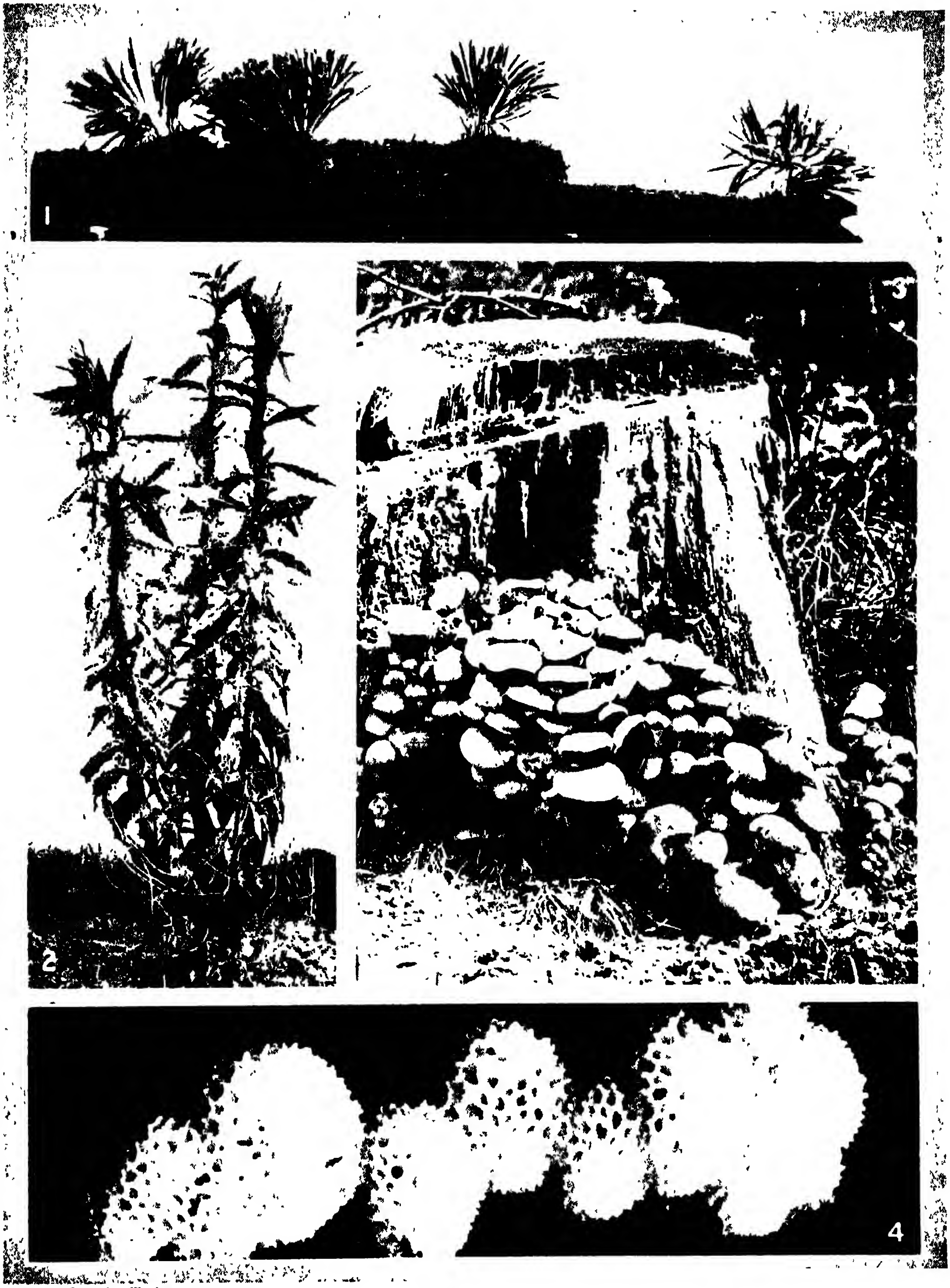
Complete parasites among plants can usually be recognized because they do not wear the worker's badge that can rarely be mistaken. They have no green coloring matter in their stems or leaves, and usually they have no well developed leaves at all. They may be white, as in some of the broom rapes, or yellowish like the dodder, but they are never green. They can make no sugar or starch, and they are known as "total parasites." They live only by stealing every bit of their food. To get it they fasten themselves to some host by various devices, for total parasites have not permanent roots.

Photo by Cornelia Clarke

The exquisite, snow-white Indian pipe is a saprophyte, drawing its food from decaying vegetable matter on the forest floor. Surprisingly enough, it is a distant relative of the azaleas.

Some total parasites, such as the dodder, are fastened only to stems and leaves. You may see this plant in midsummer as a tangle of fine, yellow, threadlike stems, with no leaves, often sprawling over shrubs and herbs. It may completely cover its host plant and seriously weaken it by stealing so much food. Many total parasites are

SOME PLANTS THAT STEAL THEIR FOOD



Photos by Cornelia Clarke

This is a pageful of plants that do not make their own food, as green plants do. At 1 and 4 are the fruiting parts of fungi called myxomycetes (mĭk′sō-mī-sē′tēz), which, during their vegetative stage, consist of a mass of protoplasm that behaves much like some of the simplest animal forms. The fungus at 3 is familiar. Here is a thriving colony of edible mushrooms growing on the rotting stump of a tree. Edible mushrooms grow in many of our woods, but it takes an expert to distinguish them from certain highly poisonous toadstools; so it is very unwise indeed for most of us to try to gather them. At 2 is a clump of daisies that are being slowly starved by the unwelcome guest that has fastened upon them. The guest is a parasite called the dodder, which shows as a skein of fine threads looped about the daisies. It is not a fungus.

This lichen is an interesting example of the way in which plants sometimes set up in partnership and live together, each one deriving certain advantages from having thrown in its lot with the other. In the case of the lichens what seems like one plant is really a combination of an alga and a fungus.

fastened to the roots of their hosts, and so grow up out of the ground much as ordinary plants do. The broom rape does this, as does also the beechdrop, which is common in beech woods.

But while none of the total parasites are ever green, there are still some other plants which are not green and which get their food from the dead leaves, branches, and trunks that lie on the forest floor. These, as has already been explained, are called "saprophytes." You have probably seen the pure white Indian pipe, which is a saprophyte. It never has any green coloring in its leaves, which are small and scalelike, and it grows only where there is abundant decaying plant material, from which it gets its food.

There are some plants which, though they live on others and are therefore sometimes called parasites, really help their hosts instead of stealing from them or injuring them. The two kinds of plants help each other. Such plants are said to be living in "symbiosis" (sĭm′bī-ō′sĭs)—which simply means "living together." One of the best examples of true symbiosis is that between plants of the pea family and the bacteria that live in little nodules (nŏd′ūl), or bunches, on their roots. These bacteria get their food from the green plant, but in turn they take the free nitrogen from the air, which no green plant can use, and combine it with other elements so that the green plant can use it.

Because plants of the pea family can live with these bacteria, it is possible for these plants to grow in soils that are poor in nitrogen. Not only do they make good growth themselves because of this, but they also enrich the soil with nitrogen. That is one reason why these plants have been so useful in agriculture throughout the world. Without the proper bacteria, however, the plants cannot grow in soils poor in nitrogen.

Another good example of symbiosis is given in our story about lichens, which tells how fungi and algae live together. There are also many cases where flowering plants have fungi growing on their roots. Most of the heath plants— rhododendron, blueberries, and azaleas—commonly have fungi associated with their roots. Many forest trees also have fungi on their roots. It is often said that the green plant supplies the fungus with food while the fungus absorbs water and mineral salts for the plant. But it has not been entirely proved that these fungi are necessary or even surely useful. On the other hand, some are undoubtedly harmful, and are true parasites.

Reading Unit No. 10

SOME PLANTS THAT EAT MEAT

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Things to Think About

How can a plant digest an insect?
How can the tiny sundew capture an insect?
What prevents an insect from escaping from the inside of a pitcher plant?
How does the trigger action of the Venus' flytrap capture an insect?
How are the bladders of the bladderworts fitted for capturing tiny animals?

Picture Hunt

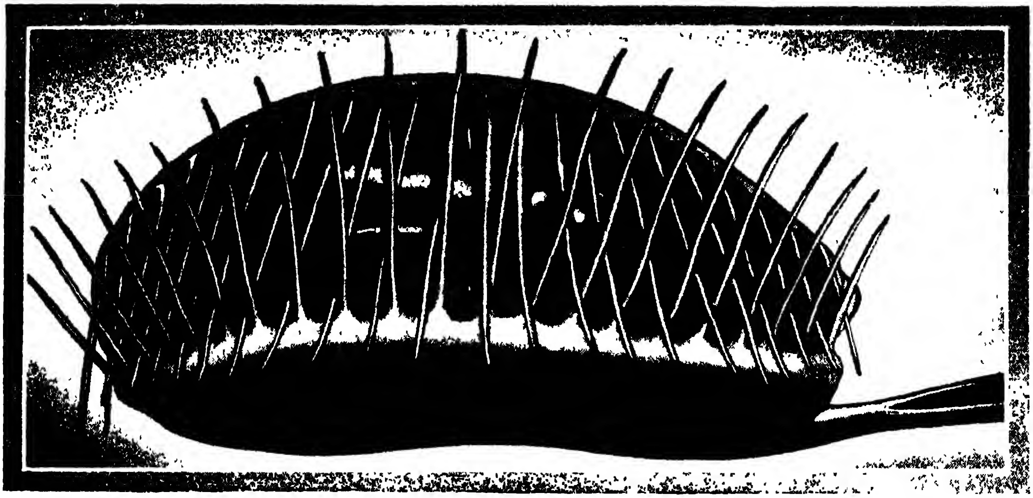
Why is the insect unable to escape from the trap? 2–60
What part of the sundew holds on to the insect? 2-61
Why cannot an insect leave the bladderwort's trap, once it is captured? 2–63
What part of the pitcher plant digests insects? 2–64

Leisure-time Activities

PROJECT NO. 1: Visit a botanic garden. Get permission to see how a Venus' flytrap works. If you can get an old pitcher plant leaf, cut it lengthwise and look for insect remains at the bottom. Look for the bristles in the pitcher, 2–61-64

Summary Statement

Insect-eating plants are tiny. They are very well equipped to capture their prey and to digest it. The pitcher plant attracts insects with sweet liquids and then traps them with its downward-pointing bristles. The Venus' flytrap has hairs which respond to touch as triggers do. These hairs fold over and trap the insect. The sundew has sticky tentacles which act as fly-paper does. The bladderwort has tiny bladders which suddenly draw in the insect and water with it. Although the water can get out, the insect cannot.



In North Carolina grows the plant called Venus' flytrap; and a fine insect trap it is, as this picture shows. Long spines grow along the edge of the leaf. When the leaf is open these spines are like a fringe, but when an insect touches a trigger hair twice, the two halves fold quickly together and imprison the victim behind the long spines. Then juices pour out on the trapped insect and it is digested and absorbed.

SOME PLANTS THAT EAT MEAT

A Few of Them Have Taken to This Strange Diet, and This Will Tell You How They Get Their Meals

MOST of the plants in the world can live quite well on the food they make themselves or on that which they can get from other plants. But there are some plants that seem to need meat too. There are not a great many of these, and most of them could live a good while without animal food. Yet about four hundred different kinds of plants do live partly on animals, especially insects, and they have curious and interesting ways of catching them.

Flies and bees and grubs would not make very appetizing food for us—fuzzy, indigestible, and horrid—but they do not seem disgusting to the insect eaters of the animal world, such as many birds, or to the insect eaters of the plant world, the "insectivorous (ĭn'sĕk-tĭv'ô-rŭs) plants," as they are called. These plants cannot chew their food as we all chew our steak, for of course they have no tongues or teeth. But without biting or chewing they still manage to get nourishment from insects very much as do the birds or fish, which do not chew their food. Of course they must catch the insect before they can eat it—and we are going to see that they have many interesting ways of doing this. But they all have much the same method of digesting their meat once it is caught.

We digest our food by the action of the digestive juices or enzymes (ĕn'zīm) which get mixed with the food as it passes through the digestive tract. These enzymes break down or digest the food, making it ready to dissolve in water better, and therefore ready to pass through the walls of the cells and be used as food.

A rather similar digestion of food takes place in the insectiverous plants. They secrete (sē-krēt'), or make, enzymes which gradually break down their insect food into material that is more easily dissolved. The food that comes from meat and insects consists largely of protein (prō'tē-ĭn), which contains a great deal of nitrogen (nī'trô-gĕn). It is probably the nitrogen in the protein that is so important to the insect-catching plants. Let us see how these meat-eating plants get their dainties.

All over the world we can find growing in

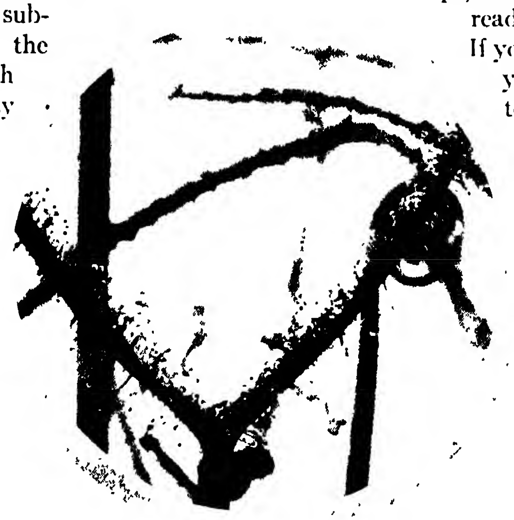
boggy places many different species of sundew. They are low herbs with either circular or thread-shaped leaves, and the leaves are covered with tiny tentacles (tĕn'tȧ-k'l) or hairs. The tips of these tentacles secrete a sticky substance that glistens in the sun, and there is so much of it that an insect may easily catch the glint of it many feet away.

Plenty of flies see the glistening sundew, and as they near it they are sure to smell the honey. If they were wise they would avoid it like the plague, for it means death for them to touch it. But that, of course, the insect does not know.

He lands on the leaf, right in the middle of the glistening bed of sticky droplets, expecting to get a good meal. But the tentacles of the sundew are sensitive to the least irritation; they soon bend and entangle the insect's legs, body, and wings, so that he finds it hard to move. The insect struggles a good deal when he finds that what he thought was to be a nice meal is actually a highly efficient fly paper. The more he struggles, the more he irritates the tentacles. These gradually bend over and tangle him more and more tightly in their deadly grip. There they hold him until he dies.

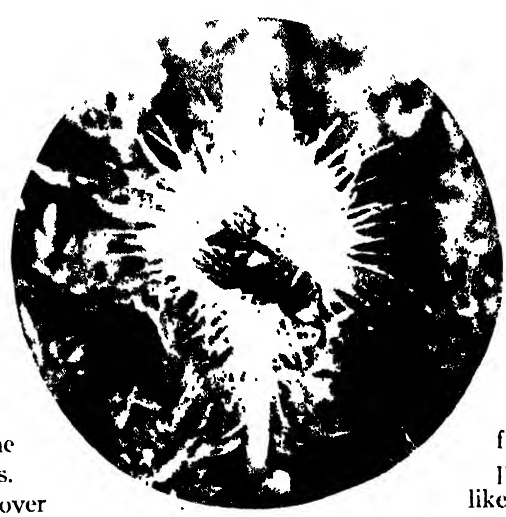
The movements of the insect seem to stimulate certain cells which secrete a digestive enzyme that digests the body of the insect, making it into food which the leaf can absorb.

After this the tentacles, with their sticky tips, bend upward again and are ready for the next insect. If you want to see it happen you may get the sundew to do it all for you. Just drop a tiny bit of steak on the glistening leaf. The whole little drama will be played out for you within an hour or two.



Photos by Nature Magazine and N. Y. Botanical Garden

Drosera, whose common name is sundew, is one of the insect-catching plants. In the picture above we can see part of a stem covered with sticky glandular hairs. Below, we see a leaf greatly enlarged to show the tiny tentacles closing over a struggling insect.



Catching and killing insects by making a sticky fly paper seems a rather strange way of getting meat. But other groups of insectivorous plants have developed equally queer methods. Instead of catching the insects with sticky glistening drops, they set other kinds of traps for them. Some have no catches or springs in the traps, but their pitcher-shaped leaves act as deadly pitfalls to all insects foolish enough to fall in. Others set traps much like spring traps that will grab the unwary insect.

In the bogs of Eastern North America there are a few species of these plants that look much like pitchers. These so-called pitcher plants differ in size and color and shape, but all of them have pitcher-shaped or funnel-shaped leaves, without any ordinary leaf blades at all. The pitchers are more or less erect, and they

have a lid; but the lid never closes and may serve only to keep out most of the raindrops.

In the Tropics of the Old World there are over sixty different kinds of pitcher plant, somewhat like our American kinds but often having ordinary leaves as well as pitchers. Sometimes these Old World pitcher plants live in the trees, and their brightly colored pitchers hang down among the foliage.

Plants That Eat Insects

All the pitcher plants invite insects to explore the inside of the pitchers by secreting honey at the mouth of the pitcher. Few insects can resist the lure of sweets, and some of them are attracted by the bright colors of many of the pitchers. Whatever the attraction, many insects do crawl inside, and then their troubles begin.

While getting a meal of honey, the insect is likely to fall part way down the neck of the pitcher, where a layer of sharp hairs, all pointing downward, keeps him from climbing out. Just below the hairs there is a "slide zone" which is so slippery that he can hardly help sliding further. Of course he does not know what this is, but he soon finds out. Once he has crawled below the fringe of hairs, he finds the slide zone so smooth that he cannot crawl back up again. The more he tries to climb out, the faster he slips down toward the bottom of the pitcher.

This is no minor accident; it means death to the insect. At the bottom of the pitcher is a small well of water in which he finally drowns. Then he is digested by enzymes and absorbed by the plant.

The Pitcher Plant's Insect Broth

Some of the pitchers are so gorgeously colored, especially in the East Indian kinds, that they attract great numbers of insects. Not one survives if he is unlucky enough to get below the fringe of downward-pointing hairs. All he does is to make part of the terrible insect broth at the bottom of the well.

Butterwort is a bog herb with a rosette of commonplace-looking leaves that have a slightly raised margin. The surface of the leaf is covered with almost microscopic glands which secrete a sticky substance. This makes the leaf into a miniature fly paper, though it can hold only very small insects, since the big and powerful ones can easily tear themselves loose. But if a tiny insect does get caught it soon dies. Once it is dead a very strange thing happens. The body of the insect is washed by the rain or dew down into the tiny trough made by the upturned margin of the leaf. This trough is very sensitive to the presence of protein food, and it starts its digestive machinery as soon as the insect is there. Slowly the leaf rolls its margin over the dead insect, completely inclosing him. And once this "stomach" is closed, it is not opened until the insect has been digested by the enzymes secreted there. Then the plant finishes the work by absorbing the digested parts of the insect. After this, it unrolls the leaf margin just far enough to make another trough, and it is ready for another meal.

Venus' Flytrap

In the pine-barren bogs of North and South Carolina grows an insectivorous plant that is known all over the world. Why it grows wild in the Carolinas and nowhere else nobody knows; but it is now cultivated in greenhouses nearly everywhere, because it is a real flytrap. Years ago it was given the name of Venus' flytrap.

Its leaves catch insects, and kill and eat them too. There is a rosette of these basal leaves, each of which is divided into valvelike halves that face each other and are hinged at the bottom. The inner face of the leaf is covered with red dots, the use of which we shall see in a moment.

On the inner face of the leaves are also six hairs, three on each half. These hairs act as triggers which spring the trap. Their action is very interesting. Touching a trigger only once is not enough to spring the trap. A trigger of the Venus' flytrap must be touched twice to catch the insect. The first touch has an effect like that of cocking a gun or removing a safety catch, and the second touch springs the trap. The second touch can be given to the same hair that was touched first or to any one of the other hairs. This second touch must come, however, within twenty seconds or less after the

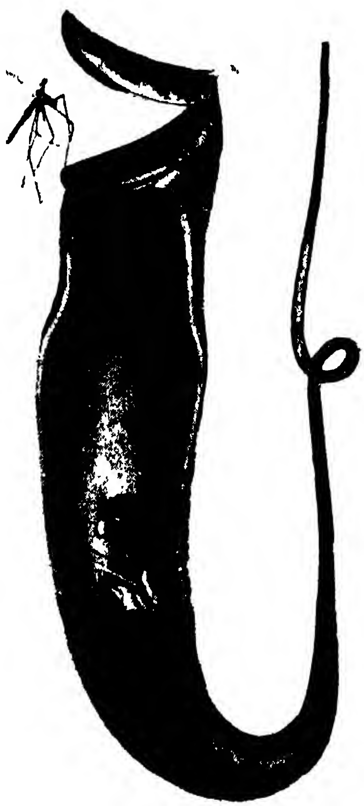
SOME PLANTS THAT EAT MEAT

The bladderwort has many little traps under water to catch tiny insects and water animals. The traps show in the picture as small black spots. In the oval one of them is enlarged and a hole is cut in the side, so that we can see in. When a tiny swimming insect strikes against the trigger hair at the mouth of the sacklike chamber, a trap door is released and the insect is sucked inside with a drop of water. The door then shuts, and the insect is digested and used as food by the plant.

first, or the trap will not close. When a trigger is touched a second time, the valve-like halves immediately fold together, trapping the insect. He is helpless because he cannot crawl through the fence of overlapping hairs which close the only exit to the prison. There is no escape for the insect now, but the plant has only begun its work.

There is another much more common group of insect-catching plants which live mostly submerged in water. They have tiny bladders in which they catch and digest small swimming animals of one sort or another. Because of these bladders the plants are known as bladderworts. The bladders are very effective and ingenious traps, though they are so small that one has to use a microscope to watch them work. When an insect or other tiny water animal comes near the mouth of one of these traps and touches a triggerlike hair, a trapdoor suddenly snaps open, sucking in the insect with a drop of water. The door closes again immediately, and the insect or other animal is imprisoned.

Glands on the inside of the little bladder then secrete enzymes which digest the body of the trapped animal, and the digested food is absorbed by the plant. Meanwhile the trap is gradually reset. The door moves back into place and is sealed tight with a sort of weather strip which prevents water from leaking in. Part of the water is slowly pumped out of the trap, and the trap is now ready to catch the next animal that touches the trigger. Any little animal that touches the trigger is sucked into the trap with a little water, very much as it would be sucked in by a medicine dropper. The bladder is elastic, somewhat like the rubber bulb of the medicine dropper; its walls are partly collapsed when water is pumped out of it, and it swells out suddenly, sucking in water, when the trapdoor is opened by the insect touching the trigger.



This is one of the strange pitcher plants. It lives in Eastern Asia and has an enormous appetite for insects. When the unlucky insect you see about to enter the trap finds himself well inside, he will have no choice but to slide to the bottom and be drowned and digested in the liquid there.

Photo by Field Museum

Reading Unit No. 11

THE CURIOUS PLANTS WE CALL ALGAE

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The explanation of red snows and the color of the Red Sea, 2–66

The unusual places in which algae live, 2–66-69

The kinds of algae, 2–66-69

The usefulness of algae, 2–69

Things to Think About

What makes the Red Sea red?

How do algae differ from other plants?

What coats certain flower pots with a bluish-green slime?

How have algae helped people find their way when lost?

What algae are important in the manufacture of dynamite?

Why can the giant brown algae of the ocean float?

Why is it said that if it were not for algae there would be no animal life in the sea?

Picture Hunt

When is the best time to observe brown algae at the seashore? 2–66

What group of algae has the most beautiful patterns? 2–68

Where does alaria live? 2–68

Leisure-time Activities

PROJECT NO. 1: Make a collection of sea weeds at low tide. Dry the algae and hang them up in your classroom, 2–66.

PROJECT NO. 2: With a microscope examine some of the slimy plants floating on ponds. Scrape off some of the green material from a tree trunk or flower pot and examine it, 2-67-68.

PROJECT NO. 3: Make a microscopic study of various scouring powders and examine the diatoms you may find, 2–68.

Summary Statement

Algae are simple plants which are noted for their love of damp or wet places and their remarkable variety of shapes and sizes. They live in snow, ice, oceans, fresh water, in hot springs, on trees—in fact everywhere where plants can live.

Photo by N. Y. Botanical Garden

When the shore of the sea is rocky and the water cold but not icy we are likely to find the rocks that are exposed at low tide well covered with brown algae. Along the New England coast the commonest kelps are Fucus and Ascophyllum, called rock weeds; these are the algae shown in our picture.

The CURIOUS PLANTS WE CALL ALGAE

Some Interesting Facts about a Group of Plants That Serve Man in a Number of Ways

IF YOU were traveling to India by way of the Suez Canal, you would come to a body of water called the Red Sea. It is so named because, for a part of the year, long stretches of it are red. Or if you were traveling in the Arctic regions you might find patches of snow and ice colored just as red as the Red Sea—and for the same reason. In both instances, the red color is due to the presence of numerous simple plants of the kind we call algae (ăl′jē).

The name alga (ăl′gȧ) has been given to that large group of flowerless plants which form the main and characteristic vegetation in water. In no climate from the polar regions to the Equator is the sea altogether free from algae, though they abound on some shores much more than on others. Certain kinds likewise abound in fresh water, whether running or stagnant, and in mineral springs. The streams of Italy containing sulphur, the everlasting snows of the Alps, and the hot springs of Iceland, have each their peculiar species. Comparatively few algae inhabit places which are not at least part of the time under water or exposed to the constant dripping of water. And wherever they may be found, great dampness is always necessary for their reproduction.

Because they are scattered through all climates and exist under so many different conditions, the species of algae are exceedingly numerous and differ from one another in form and size more than do any other groups of plants where the structures within the group are so much alike. Some are so exceedingly tiny as to be invisible to the naked eye, except in masses; one has to use a microscope to make out their form and structure. Others, growing in the Pacific Ocean, have stemlike structures longer than some of our tallest forest trees; still others have leaflike structures wider than the large leaves of the palms. Some are simple globules or spheres, consisting of a single cell; some are mere strings of such cells, more slender than a hair from your head; and there are some that are composed of branching strings of cells. A few possess leaflike structures which may be formed of a delicate,

perforated network much like lace or the skeletons of leaves.

So we find that some algae are simple and of one cell only—hence called unicellular (ū′nĭ-sĕl′ū-lâr)—while others may be many-celled, or multicellular (mŭl′tĭ-sĕl′ū-lâr). When the unicellular algae divide, they form new individuals; hence cell division and reproduction are the same.

In the multicellular algae, however, we find that the reproduction takes place only in certain parts of the plant, while the rest does "vegetative work" only, such as manufacturing food and absorbing minerals.

When the multicellular algae are divided into vegetative and reproductive portions, there is a change in the structure of each part. For example, the vegetative portions of many sea algae consist of parts resembling the stem and leaves of the flowering plants, although these parts are not so complete as they are in the flowering plant, and do not have so many duties to perform as similar parts in the flowering plant. The rootlike part attends only to the business of holding the plant to one spot, and so far as we know has nothing to do with the taking in and carrying of materials. Each part of the plant absorbs its own minerals and gases and water from the water in which it is living. Each cell also makes its food in the light. The flattened portion of the seaweed, although not the exact equivalent of a tree leaf, has the same green coloring matter in the cells and manufactures its food in the light.

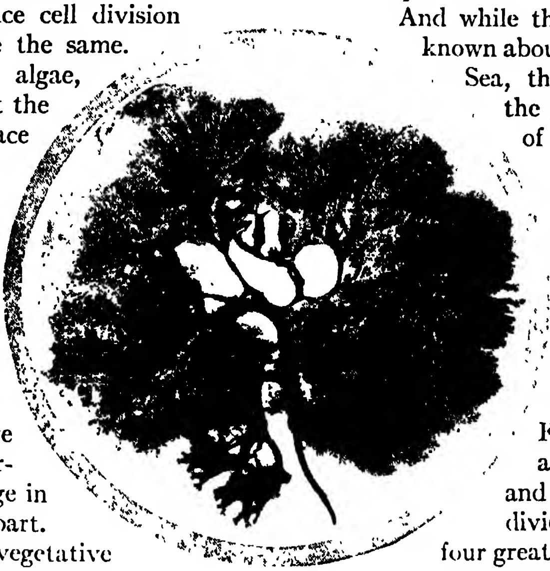


Photo by N Y Botanical Garden

Above is a feathery green alga, Cladophora, growing on a coarser red alga, Chondus crispus, also called "Irish Moss." Both are marine algae, but many kinds of the green Cladophora grow in fresh water.

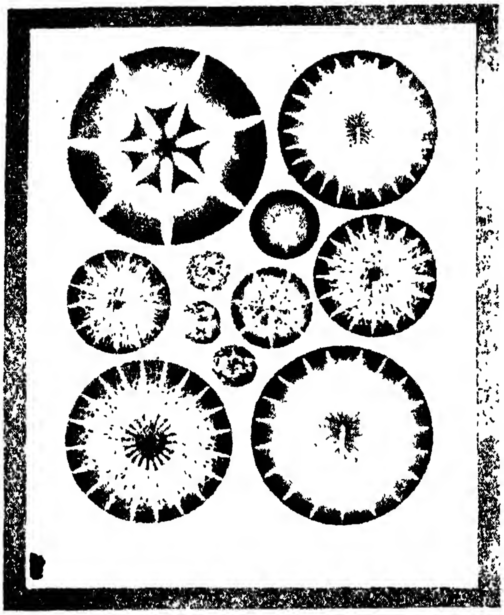
The Thousands of Kinds of Algae

When the Romans invented the word "alga" for flowerless plants that grew in the sea, they had no idea that some of the algae grew in fresh water, on tree trunks, or even on their doorsteps. In fact it was not until we had the modern microscope that we knew that algae are of thousands of kinds, ranging in size all the way from the kelps, which may be several hundred feet long, to little plants so small that it takes five million of them to cover a square inch.

And while the Romans may have known about the algae in the Red Sea, they knew nothing of the green scum on ponds, of the red snow in the Arctic, or of the brown seaweeds in the North Atlantic. We have since come to attach a good deal of importance to these colors of the algae, quite apart from their beauty. For their colors tell us a good deal about them and where they grow. We divide all the algae into four great groups based on their color and structure.

If we scrape the side of an old, damp flowerpot or the side of the doorstep, we often gather a thin, bluish-green slime. Under the microscope, we find that this slime is made up of a mixture of small plants and animals, some of them unicellular and some multicellular. Most of the plant cells, whether they be single cells or groups arranged in a thread, are bluish-green in color. This color is really due to the mixture of two pigments in the cells, the ordinary green one which we call chlorophyll (klō′rō-fĭl) and a blue one. The cells of these algae will always be covered with a substance like gelatin, and this explains why they are nearly always slimy to the touch. In one kind, the filaments resemble strings of beads and are embedded in masses of this gelatinous material. These masses may become as large as a hen's egg.

In addition to growing on flowerpots and doorsteps, many of the blue-green algae grow in the soil, in the sea. and even inside other



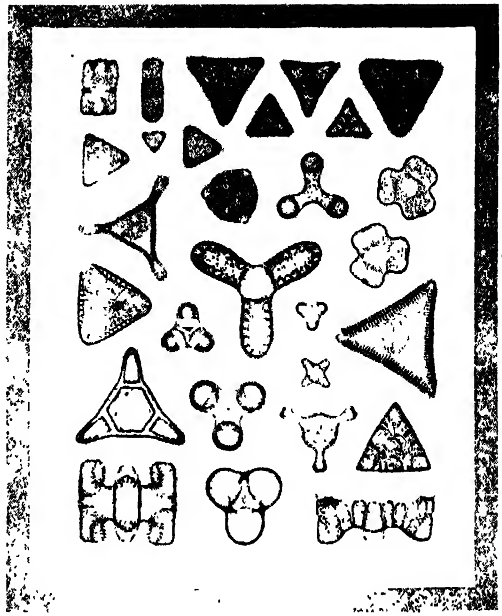


Photo by N. Y Botanical Garden

All these forms, so beautiful in pattern and symmetry, are diatoms. If they were not enlarged we should not be able to see the individual forms at all, and yet the shells of these one-celled plants sometimes collect in beds many feet thick. Because of the silica in their walls diatoms are sometimes used in scouring powder. Theirs is a plant race immensely old, as we know from their fossil remains.

plants and animals. In the ocean, an alga called Anabaena (ăn′ȧ-bē′nȧ) lives happy and well protected inside certain simple sea animals. Others reside on hairs of creatures such as the sloths of South America. Sometimes they get into our drinking water and make it unpleasant to the taste, though not poisonous. The bad taste is due to certain substances formed inside the cells.

Many a lost lumberman has been able to find his way out of the wilds simply because he knew on which side of a tree algae and moss grew. Much of this vegetation is a green alga called Protococcus (prō′tô-kŏk′ŭs), which helps to stain the north, or moist and more shaded, side of a tree a vivid green. If we scrape some of this green coating and place it under the microscope, we find that it is made up of small cells that look like tiny green balls. These green balls contain chloroplasts (klō′rō-plăst), which give them their attractive green color. No other coloring is present.

Photo by N. Y Botanical Garden

In contrast with the tiny algae called diatoms is the enormous blanketlike Alaria, an alga whose home is in the cold waters off Alaska. This specimen measures five feet, ten inches across.

But many of the green algae, nearly all of which grow in fresh water or moist places, are not so simple as Protococcus. One of these, Spirogyra (spī′rō-jī′rȧ), coats ponds with a green scum that is sometimes called "frogspit." The name of this plant is a good one, for under the microscope each cell contains a long, spiral chloroplast. Some, including Ulothrix (ū′lô-thrĭks), grow either in fresh or salt water, and develop structures at the base which enable them to cling to rocks. Still further developed is the sea lettuce, so called because it grows in sheets which resemble lettuce leaves. This plant grows only along tidal shores..

One of the most curious groups of plants belonging to the green algae is the diatoms (dī'ȧ-tŏm). These are microscopic forms which live in streams, ponds, and seas, and under the microscope they look somewhat like small pill boxes. Indeed, they consist of two halves, or "valves," as they are called, and the one fits very neatly over the other. And they are covered with very beautiful designs that are as regular as the cuttings of the finest jewels. But even though these tiny plants have such rare beauty, they are better known for their chemical character. The chemists, who have made many tests, have found that diatoms contain much silicon dioxide (sĭl'ĭ-kŏn dī-ŏk'sīd), the substance we commonly know as sand.

Why Diatom Shells Are Valuable

When diatoms die, the pill-box shells sink, for they are heavier than water. Because of this there are regions in Germany and America, once covered by the sea, which have great deposits of the shells of these organisms—sometimes fifteen or more feet in thickness. These deposits are valuable, not only because the silica can be used as a polishing material, but because it is an ingredient of dynamite. A single thimbleful of such earth may contain over two million skeletons of these strange plants.

Most of the brown algae occur in the sea. It is strange that even though they appear brown or olive in color, their cells contain, in addition to the brown coloring matter, the normal green coloring matter of chlorophyll. They are to be found on all seacoasts, being more abundant and noticeable in the cooler waters. Often they look like strange land plants that have taken to the sea and have lost their flowers. Nearly all of them have rootlike "holdfasts" which anchor them. Many have curious bladderlike floats full of air, which keep the branches floating.

The Strangest of Brown Algae

Perhaps the strangest of all the brown algae is the gulf weed. On his first voyage to America, Columbus ran through great patches of this plant. These patches covered large areas, and it was very hard for the ship to sail through. The region has sometimes been called the Sargasso (sär-găs'ō) Sea, from "Sargassum," the Latin name of this strange brown seaweed which grows so densely. The "sea" is covered with millions of plants, which float about in a great mass. Though they are far from any land they continue to grow extensively.

The majority of marine algae, however, are not the brown algae, but the red algae. The reddish color is given to the plants by a red coloring matter which is present in their cells in addition to chlorophyll. Generally they are found below low-tide level, and may grow at depths as great as two to five hundred feet. Most of them occur in tropical or subtropical ocean waters.

In such a large group of plants as the algae, we should naturally expect to find some that can be used not only by men but by other animals. Oceans and large bodies of fresh water support many algae, especially the smaller ones. Just as we have some people who live on vegetable material entirely, so we have certain fish which are vegetarians and are so equipped that they are able to strain the small plant cells from the water. These smaller fish are in turn eaten by larger fish. Really, therefore, the algae are the original source of food for all life in the water.

The Good Work of Algae

Algae tend to keep water pure. You have probably noticed that from the green scum which may be floating on bodies of stagnant water, gas bubbles arise. For like other plants, the algae give off large quantities of oxygen, and it is this gas which aids in purification.

For many years the people of Iceland have collected large quantities of seaweed to spread on the land. This is much like what we do when we allow leaves and other materials to rot and then use the mold to fertilize the land. Kelp—one of the brown algae—is gathered on the Pacific coast and used as a source of certain salts, especially iodine.

In some countries, algae are used as a source of food. Blanc mange, for instance, is made from a European seaweed.

BOTANY

Reading Unit No. 12

MUSHROOMS AND TOADSTOOLS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why fungi are interesting, 2–71
Where fungi live, 2–71
The structure of fungi, 2–71-74
Why fungi cannot make their own food, 2–74
How fungi reproduce, 2–74-76
Some harmful and some useful fungi, 2–76

Things to Think About

In what kinds of places do we find fungi?
In what way are fungi different from higher plants?
What important substance do fungi lack? What is the result of this lack?
Why do dead trees in the forest finally disappear?
What do spores do for fungi?
Why are toadstools poisonous?
What have fungi to do with cheese?

Picture Hunt

What do mushrooms produce? 2–71
Why is the invisible portion of a fungus harmful to a tree? 2–71
Why do some fungi shine at night? 2–72
What causes "fairy rings" to appear? 2–72
What kind of fungus is the earth star? 2–73
What fungus looks like a nest? 2–73

Leisure-time Activities

PROJECT NO. 1: Make a collection of fungi and learn their names and uses, 2–73.
PROJECT NO. 2: Moisten a piece of bread and cover it with a tumbler or jar. Keep it in a warm, dark place and after a week study the hyphae and spores with a lens and microscope, 2–74-76.

Summary Statement

Fungi are plants without chlorophyll, stems, leaves, or real roots. Some are one-celled, some many-celled. They include bacteria, yeasts, molds, mushrooms, and toadstools. Because they cannot make their own food, fungi are either parasites or saprophytes.

Photo by Cornelia Clarke

Here is a row of the fruiting structures of a fungus sometimes called a mushroom, sometimes a toadstool. The stalk is not a true stem, nor is the cap either leaf or flower. Flower or leaf or stem these simple plants do not have. Under the ground is the mass of hyphae which is their vegetative part. When fruiting time comes, these stalked caps rise into the air bearing the spores in plates on their under surfaces.

MUSHROOMS *and* TOADSTOOLS

This Is a Tale of Various Fungi, in Many Ways the Most Interesting of Growing Things

THE plants we call fungi are most noticeable and most numerous at a time when the more aristocratic members of the plant world have departed. To those of us who enjoy mysteries, there can be no lack of interest in the fungi (fŭn′jī). In many respects they are the most mysterious of all plants. In their origin, their shapes, the rapidity of their growth, the shortness of their life, their ways of reproduction and their great numbers, they are very different from every other kind of plant we know. In studying their histories and habits we walk amid surprises.

Photo by N. Y. Botanical Garden

The fruiting bodies of this fungus grow in a knot hole in a tree. When its spores fall on a tree wound and sprout, the hyphae eat into the wood, digesting it, and making it decay. This causes a heart rot and may kill cells in the sap wood.

Fungi may be found in all sorts of places. Some may live on the dead bodies of plants or animals, others on the living. Stagnant water is the home of some, while soil or leaf mold is preferred by others. A few seem to enjoy the quietness of caves and dark holes, where they may cover the walls with their feltlike growth. Others inhabit our houses, attack our food and clothes of every kind, and the timbers of our homes. There are even some which seem to get enough food from the paste we use for our wall paper or our books.

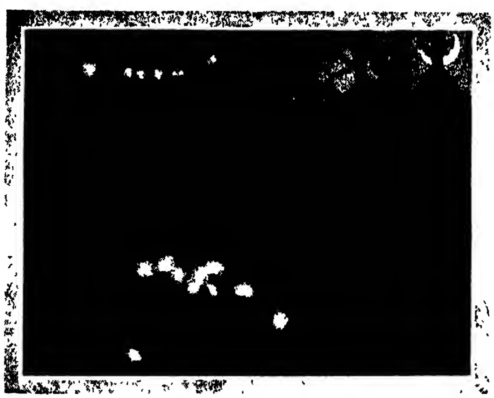
The simplest fungi consist of a few cells, either separate or joined; or of cells joined together in branched filaments (fĭl′ȧ-mĕnt), or threads, that are able both to absorb materials and to reproduce Between these and the common mushroom—which we regard as showing the highest development among the fungi—there are numerous intermediate forms, more or less complex. Some are shell-shaped and others shrubby. Some form large round balls, splitting into starlike

Photo by N. Y. Botanical Garden

Have you ever seen mushrooms growing like this in a "fairy ring"? It *does* look as if Titania and her tiny fairy dancers might have planted this wee hedge around their ballroom! What really happens is almost as surprising. The hyphae of the fungus start in a group as usual and spread out underground in a constantly enlarging circle. As they grow they use up the food material in the soil, and the oldest hyphae in the center are starved out. This makes a barren place which increases as more food is used and more hyphae die. Each year during favorable weather the hyphae develop the fruiting bodies, which form in a ring where the more active hyphae are seeking a better food supply. The "fairy ring" thus grows ever wider.

expanded rays, while others are crowned with peaked caps. Some are cup-shaped, bell-shaped, or trumpet-shaped. One forms a beautiful little goblet raised upon a slender stem or holder. Really there is almost no end to the curious shapes that various kinds of fungi may have.

Fungi in general seem to have adopted quiet tones quite suitable to the places where they generally live. Yet we find some of them dressed in very gaudy colors. Some species are of a brilliant scarlet, others of a bright orange. Many are yellow, while a few are royal purple. We may find almost every color, from the purest white to black. Some are as soft as velvet, others glisten as if sprinkled with mica.



The soft, glowing lights in this Brazilian forest come from certain tropical fungi which are luminous at night. Their light is due to bacteria which live on them—parasites living on parasites!

There are a number of fungi which are unicellular (ū′nĭ-sĕl′ū-lȧr)—that is, consisting of single cells—such as the bacteria (băk-tē′rĭ-ȧ) and yeast. These we shall describe at a later time. The larger number are made up of filaments or chains of cells—each filament is usually called a hypha (hī′fȧ). Masses of hyphae (hī′fē)—the plural of "hypha"—make up the body of the plant and are called mycelium (mī-sē′lĭ-ŭm). The entire structure of the mycelium is usually uniform. There are no roots, stems, or leaves.

Although the fungi are generally of a loose cellular structure, they show an astonishing variety of consistency. In our rambles about the woods, we may notice that each kind of fungus has a different texture. They range from a watery pulp or scum to a fleshy,

MUSHROOMS AND TOADSTOOLS

Photos by Cornelia Clarke, N. Y. Botanical Garden, and General Biological Supply House

On this page are shown some of the curious, often beautiful forms taken by the fruiting structures of various fungi. 1. Helvella, which bears its spores in cups or disks. 2. Bird's nest or cup fungus. 3. *Amanita muscaria*, a deadly poisonous toadstool. 4. Schizophyllum, a beautiful white fungus which grows on dead trees. 5. Earth star, a kind of puffball whose outer skin splits and pulls backward into a star pattern as it explodes. 6. A mushroom fungus whose cup-shaped fruiting structure grows thickly on the stems of some trees. 7. Lepita, one of the common fleshy sort of mushroom. 8. *Coprinus ebulbosus*, an edible mushroom, though not the one we see oftenest in our markets. Should you ever have dreamed there were so many strange and fascinating fungi? And even all those shown in this chapter do not begin to tell the story.

leathery, or even hard, mass. Some are mere threads of airy cobweb, spreading like a veil over decaying matter; others look like irregular masses of hard wood.

Because of their simple structure, the fungi have the ability to grow almost indefinitely,

Photo by N. Y. Botanical Garden

This kind of fungus, commonly called stinkhorn because of its foul odor, sends up its fruiting structure very fast. This picture was taken only a few hours after the fruit part began to grow; the nickel under it shows the size it has attained. The fly is feeding on its spore mass.

depending upon the amount of food they can get. The largest kinds often grow to an unbelievable size, almost like those that we read of in fairy tales. One of the shelf fungi, which grows on decayed trunks of trees, has been found over seven feet across and weighing over thirty pounds. One may often come on a puffball measuring a foot and a half in diameter and weighing many pounds. They are called puffballs because when they mature they dry out and open. Then at a pinch from the fingers or a good puff of wind, large numbers of "spores," like a puff of smoke, can be forced from the ball.

Why Fungi Cannot Make Their Own Food

Although a few fungi have a greenish color, no fungus (fŭn′gŭs)—the singular of "fungi"—has the chlorophyll (klō′rô-fĭl) green that is present in most green plants. It is therefore impossible for fungi to make food as ordinary green plants make it. They either steal food outright from living plants or animals, or else they live on the dead remains of these. Those that steal their food from the living plants or animals are the "parasite (păr′ȧ-sīt) fungi," and they often cause disease to plants and animals, including man. But those that live on the remains are called saprophytes (săp′rô-fīt). Truly some of these fungi are among the garbage men of the plant world, and very efficient ones. Everywhere they are before us. Almost as soon as a large oak tree dies, there are a number of these fungi which begin their work, and finally they will reduce the dead tree almost to a powder.

Below is the fungus called bread mold. The hyphae are very fine and white but the spores—borne in spore cases raised on stalks—are black.

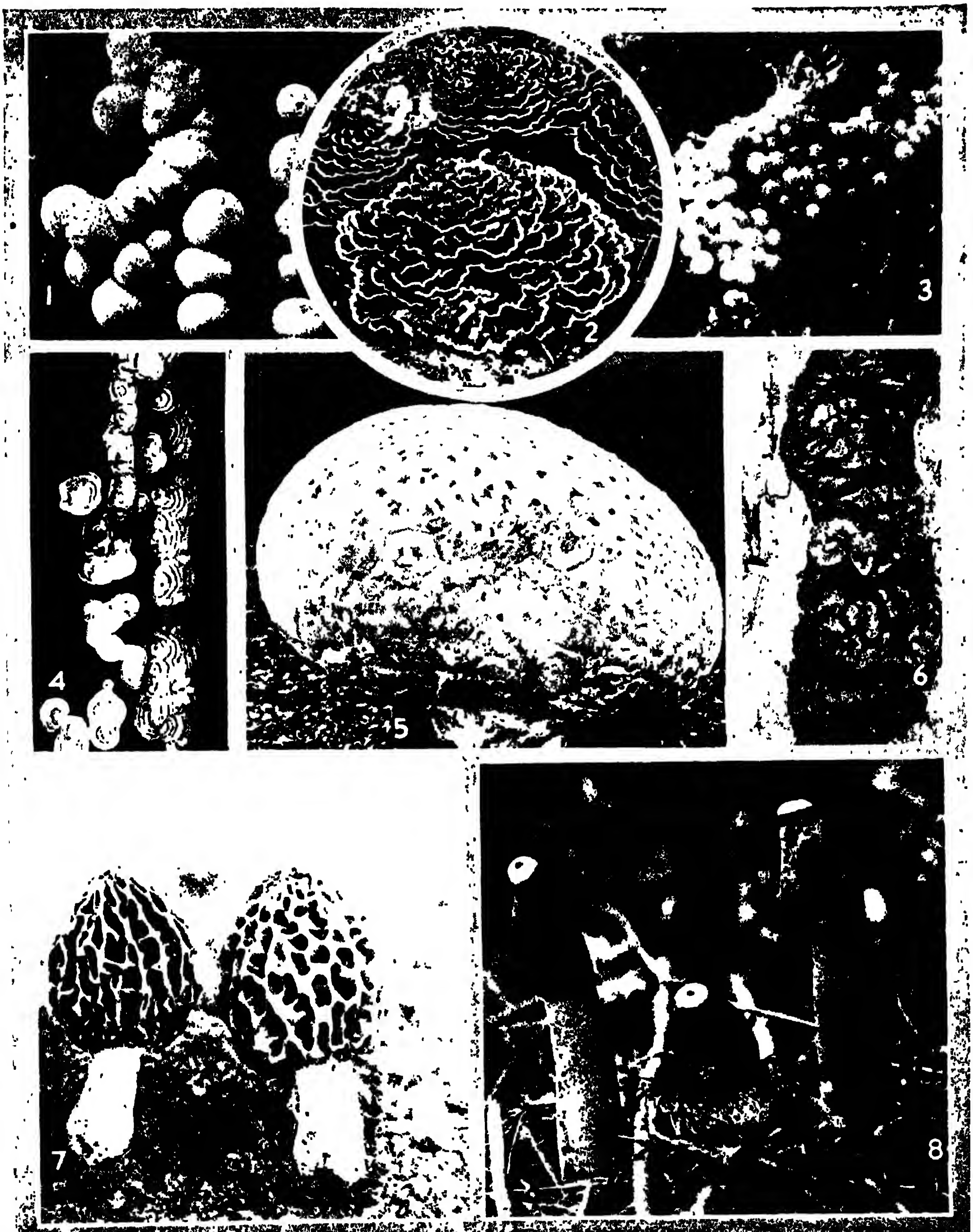
Photo by Nature Magazine

Photo by Cornelia Clarke

Here is a fungus which has chosen the chrysalis of a moth as its host.

Immediately after the death of any vegetable substance, and often before its complete death, an array of fungi of various kinds is hard at work breaking down its material and using it as food. The soft materials are rapidly reduced to a fluid or gaseous state. The hardest woods finally yield to the action of the fungus army. When a log of one of our finest trees is attacked by fungi, it soon becomes only a mass of rotten wood, and eventually even the rotten wood disappears. The fungi have used the wood as food.

You may well wonder how these plants reproduce. If we allow a piece of stale bread



Photos by Cornelia Clarke, Nature Magazine, and N. Y Botanical Gar

Have you ever stepped suddenly on a puffball as you were walking along in the woods? It has been maturing its thousands of dustlike spores, and now if your foot so much as touches it—pop! it bursts open and the brown spores fly. On this page are two or three different kinds of puffballs, as well as various other sorts of fungi. 1. In this stage the pear-shaped puffball is edible. 2. This fungus decorates its host with row on row of pretty ruffles arranged in rosettes. 3. Mycetozoa is a tiny slime mold, here seen growing on a damp, decaying log. It looks like a puffball, but is really a much simpler fungus having no hyphae. 4. *Polyporus conchifer,* here growing on a log, has delicate, shell-like markings. 5. This huge puffball is named *Calvatia pachyderma*—the latter word means "thick-skinned." 6. The wrinkled mass of this fungus on a decayed tree looks gruesomely like human brains. 7. This is Morella, an edible mushroom of quaint design. 8. Here are more stinkhorns, which give off a foul odor. They grow in the October woods.

to stand in the open air for a few days, especially when there is plenty of moisture in the air, we soon find a grayish, cobwebby growth covering the bread. From the hyphae of this growth, we could find branches with swollen, black tips. Each one of these swollen tips is really the home of a great many heavy-walled cells. Such cells are called spores. These spores are so small that they are carried in air, and when they settle under favorable conditions they will grow and produce new plants. They are sometimes called seeds, but this is not the right term, for they are much simpler than real seeds, such as we find in apples or grapes. Millions of these spores are continually floating in the air we breathe, floating in the water we drink, and lying in the dust and dirt of the soil

How Spore Production Varies

The fungi do not all have spores formed in the same way as in bread mold. While the same general method of spore production is common to them all, the different groups vary not only in the structures producing spores but also in the number of spores. In bread mold the spores are borne in a globular structure in great numbers. In the cup fungi the spores are usually in little tubes—eight spores in each tube—and these are shot into the air when they are ripe. In certain others, like our common mushrooms, the spores are borne on little pegs projecting from the inner sides of the gills.

We have already learned that many saprophytic fungi are of great value in aiding the decay of dead material. Otherwise leaves, branches, and logs would accumulate in great piles in our forests and only fire could get rid of them. These fungi have still further usefulness. Many of the mushroom group are used as a source of food. A common one, which may be bought in stores, is called Agaricus (ȧ-găr'ĭ-kŭs). When cooked with meats, it gives them a fine flavor. Morels (mŏ-rĕl') are everywhere looked upon as a valuable and delightful article of food. They grow generally in woods during the spring and early summer, and have a much-wrinkled cap, the size of a hen's egg, on top of a hollow stem—but don't eat any of them if you have only this description to rely on! Truffles form a delicacy in France and Italy They appear as underground puffballs—six inches to a foot beneath the soil—usually attached to the roots of oaks. Dogs and pigs are trained to find and dig out these toothsome little fungi.

But not all mushrooms are edible. In our walks about the woods, we often see some which are extremely poisonous. One of these, very beautiful in appearance, is called Amanita (ăm'ȧ-nī'tȧ). It is very deadly. To the mushrooms that we cannot use as food some people have applied the term "toadstool."

We use many kinds of plants to do work for us, and fungi are no exceptions. A number of molds are commonly used in the making of various kinds of cheese. These seem to be necessary for the ripening process. In this way we get our common cheeses, Roquefort, Stilton, Swiss, and the rest. Each of the molds is quite different in the materials it produces, even though each looks much like the common mold on bread.

The Damage Caused by Fungi

Fungi are a good illustration of the fact that agencies which are generally beneficial are sometimes destructive. While helping to remove much waste material, these plants sometimes carry their operations so far as to cause much damage by their rapid growth. Some of the most destructive diseases of grain crops are caused by the work of parasitic, microscopic fungi which may attack the flowers or the leaves or the stems of the plant. The smuts and rusts that we have all heard about cause much loss in our corn, wheat, and oat crops. The fungus which produces potato blight has made the raising of potatoes troublesome work. In Ireland, the potato crop was so injured at one time that a great famine resulted.

Reading Unit No. 13

A PLANT THAT IS TWO PLANTS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why lichens are called "pioneers," 2–78
The double make-up of a lichen, 2 78-79
The color of lichens, 2- 79
Why the lichens show true symbiosis, 2 79
How lichens reproduce their kind, 2–80
How man can produce new kinds of lichens, 2- 80
How lichens turn rocks into soil, 2–80
How litmus dye is made, 2 80

Things to Think About

Which two types of plants make a single lichen?
How do the two kinds of plants in a lichen help each other?
What type of life is illustrated by lichens?
How is it possible to produce new lichens?
How do lichens change rocks into soil?
How do lichens help furnish food for Eskimos and reindeer?
What dyes have been made from lichens?

Picture Hunt

What animal thrives on lichens? 2–78
Is "reindeer moss" branched or unbranched? 2–79
Which of these lichens have you often seen on your rambles? 2–80

Leisure-time Activities

PROJECT NO. 1: Make a collection of common lichens, 2–78-80.
PROJECT NO. 2: To learn the uses of litmus, place blue and red litmus papers in acid—for instance, vinegar—and in ammonia water, 2–80.

Summary Statement

Lichens are generally found ` temperate and cold regions, growing on rocks, trees, and on sandy ground. They are interesting because one part of the plant consists of food-making algae and the other part of fungi which absorb water and minerals. Each one is helped by the other. This mode of living is called symbiosis. Lichens provide food for reindeer and Eskimos. Certain dyes can be made from some of them.

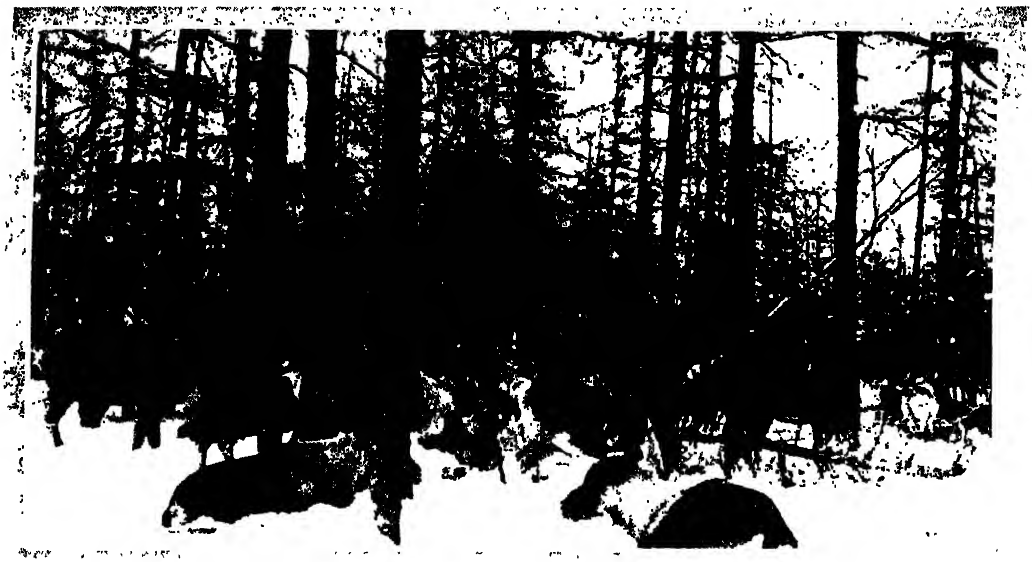


Photo by American Museum of Natural History

What can the reindeer find to eat in the snowy Arctic? Their ability to stand great cold would not do them much good if they had no food. Often it is a certain lowly lichen which alone keeps the reindeer alive. This lichen, as is the way with the lichen kind, is really two plants living together. It is nicknamed "reindeer moss" because the reindeer eat it, but it is really not a moss at all.

A PLANT THAT IS TWO PLANTS

Whenever You See a Lichen Clinging to a Rock, You Are Looking at Two Very Different Plants That Have Learned to Live as One

LICHENS form one of the most peculiar groups of plants. Even though they are plants, they have a very different structure from that of any other plants we know. As we look at them growing on the hardest of rocks or clinging to tree trunks, their appearance convinces us that they are very different from any other group of plants.

Some people call them "pioneers of the plant world," for without exception they are found where other plants find it hard to grow, because either the climate or the soil is unfavorable. They seem to thrive at the outposts of plant life. In the temperate and subarctic regions they reach their best development, especially where there is much rain. Most of the vegetation on the tops of mountains and in the Arctics, where grasses and other plants find it difficult to grow, is made up of lichens (lī'kĕn). Some prefer to inhabit the storm-swept seacoasts. A few forms actually cover vast areas in the north countries, and become useful to man.

What a variety of shapes and appearances these plants present! In their simplest forms they may look like a collection of powdery little grains. Some form inklike spots on the tops of posts and fallen trees; others remind one of flour sprinkled over shaded rocks; still others are bright green and look like gaudy designs posted on rocks and trunks of trees. The larger lichens seem to be more complex, and look shrubby and tufted, with stems and branches like very tiny trees.

Now one of the most interesting things about lichens is the fact that a single lichen plant really consists of two plants growing together. From the outside you see just a lichen, a gray or brown patch staining a stone

Photo by N. Y. Botanical Garden

From this close view of a clump of "reindeer moss" we can see why it has been called a moss when it is really a lichen. In outward appearance it does look somewhat like a moss—more so than most lichens do. But we know that its inner structure and its way of life are quite distinct from those of other plants.

or the bark of a tree. But inside there are two plants, so intermixed that for hundreds of years they were supposed to be one.

One of these is usually a green or blue-green alga (ăl′gȧ) of the single-celled type, such as Protococcus (prō′tō-kŏk′ŭs); it may be a different alga in different kinds of lichens. But like all green and blue-green algae (ăl′jē)—we have told you about them in another story—it contains chlorophyll and therefore makes its own food, as do other green plants. The other part of the lichen is a fungus, and lives as a parasite (păr′ȧ-sīt), as many fungi do. But this one does not injure its host, or the plant on which it lives. Sometimes the lichen will have in it very much of the alga, and therefore show a definite greenish appearance. Commonly the lichen will be grayish or even brownish, and in such cases not very many alga cells are present.

The fungus, like many of its relatives, would die if it could not get food. In this way it is as helpless as an old beggar who cannot earn his own living. So the fungus needs the food that the alga can make and supply. Hence the fungus is in one sense parasitic upon the alga. How then does the alga benefit? It is surrounded by a fibrous net of fungus filaments, or threads, which protect it and allow it to grow in places, such as the sides of rocks and cliffs, where it could hardly grow otherwise. Also these filaments are so arranged that they hold water; and thus the algae cells have plenty of water for their use.

So we find the alga supplying food for the fungus, and the fungus supplying water and protection for the alga. This kind of life together for mutual benefit is known as symbiosis (sĭm′bī-ō′sĭs). It produces an entirely new plant. The lichen is so well constructed that it can live a long time without rain, the alga and the fungus keeping each other in a state of partial animation. When rain finally comes, the fungus will absorb water and the alga will be able to make food.

All plants have some means of reproduction, and although lichens really consist of two kinds of plants, they have developed a

method of reproduction. At various intervals they produce small, roundish bodies which are shed and scattered about mainly by the wind. These bodies, if we look at the inside of them, are seen to be made up mainly of a tangle of filaments of the fungus inclosing a number of cells of the alga. It always seems as if the fungus is clasping the algae cells as tightly as it can to prevent them from escaping. When conditions are favorable for growth, these small bundles of lichen begin to develop into larger plants. This is indeed a simple and efficient way of reproduction.

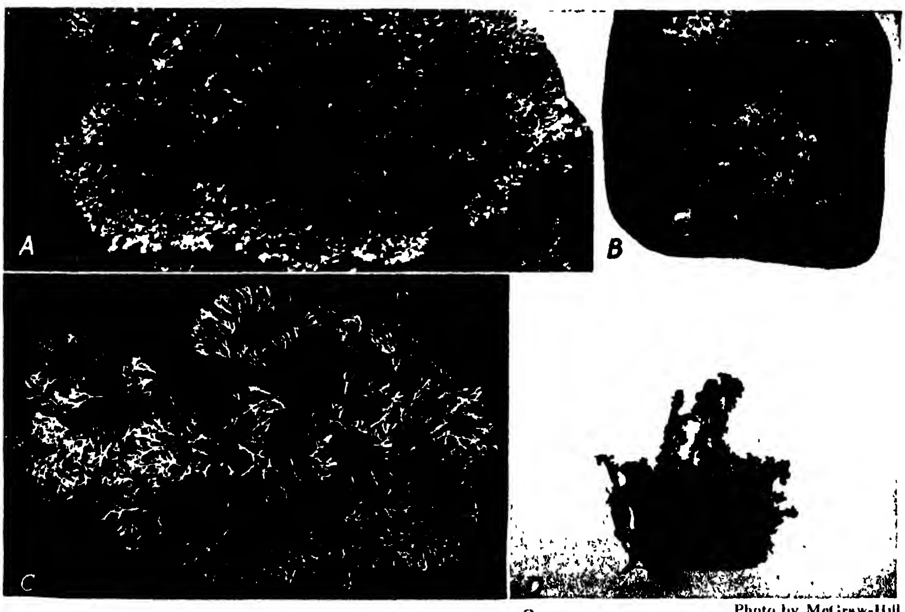
Since it was discovered what lichens really are, scientists have made some remarkable experiments. They can take a living fungus and a living alga, and allow them to grow together. In this way they can produce artificial lichens, which we should not find growing naturally. Who knows but that we shall be able, in the future, to go to a florist, order any kind of lichen we wish, and have him grow it for us in his greenhouses?

Although lichens may not seem to be of very much importance, they actually are of great value. Since they are usually the first plants to creep over exposed rocks, they form there the first soil which may later be used by other plants. The filaments of the lichen hold tightly to the surface of the rocks and in drying and shrinking gradually loosen small chunks of rock. Much soil in rocky places has probably been formed in this way.

In the extreme north countries, some kinds of lichens furnish food, not only for such animals as reindeer, but also for man. We could walk for miles over land which has nothing growing on it except lichens. One kind of lichen which grows widely is eaten by the reindeer and so is called the "reindeer moss." Iceland moss grows all over the north, and the Eskimos gather it in large quantities and dry it. When ground into meal, it can be used easily as food, and consequently is very useful.

Our grandfathers did many things very differently from the way in which we do them. We have an example in the making of dyes. Now we depend on large factories to make our dyes, mostly by chemical means. But in the olden days, dyes were made mostly from different kinds of plant materials. Many homes then took the place of factories. And in those times, lichens were valuable as the source of some dyes. There were two dyes especially which were produced in large quantities: one a purple called archil (är′kĭl), and another a crimson called cudbear.

Still another lichen is widely used to make "litmus paper," for it contains a dye that turns red when dipped in acid and blue in alkali. It can therefore be used as a test to find out whether solutions are acid or alkaline.



Here are four types of lichen, some of which you will probably recognize. At A is a leafy type, bearing cup-shaped fruiting bodies and growing on a rock. At B is a type forming a white crust that cannot be separated from the rock. The black dots are fruiting bodies. C and D show erect, shrublike forms of lichen.

Photo by McGraw-Hill

Reading Unit No. 14

HOW MUCH DO YOU KNOW ABOUT MOSS?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What mosses look like, 2-82-85
Where to look for mosses, 2-82-83
Sex in mosses, 2-83-84
How new mosses are reproduced, 2-84-85
Spore production in mosses, 2-85
Alternation of generations, 2-85
Where peat comes from, 2-85

Things to Think About

What color is characteristic of mosses?
What common moss is easily found?
Where are the sex cells of the mosses?
What does the fertilized egg of a moss develop into?
What do spores of a moss develop into?
How do mosses illustrate "alternation of generations"?
What moss, usually found in bogs, turns into peat?
How did mosses help save lives during the World Wars?

Picture Hunt

What makes the green carpet you find in the woods? 2-82
In what structures are the eggs and sperms of mosses stored? 2-83
What makes up the asexual generation in mosses? 2-83
Into what do moss spores develop? 2-83
Is the sexual generation of a liverwort a branched or unbranched structure? 2-84

Leisure-time Activities

PROJECT NO. 1: Grow mosses in a tank prepared by filling the bottom with a layer of gravel covered by a layer of humus. Water when necessary. Keep a glass cover on the tank.

Summary Statement

Mosses are tiny, simple, green plants that resemble small cedars or spruces. They prefer moist, shady places. The green part is the sexual generation and bears the sex cells in special organs. When the sperm and egg meet and fuse, a tall spore-bearing shoot appears above the green part. The spore-bearing part is the asexual generation. Spores are shed and give rise to the green sexual generation.

Photo by Govt. of New Zealand

In just such a place as this, on the earth under the trees and ferns, mosses love to grow. They are so small that we cannot see them in our picture. But the next time you walk through woods in the early spring when the ground is wet, or the next time you stand on the damp border of a pool, look for a carpet of tiny green plants; you will be sure to find one or more kinds of moss.

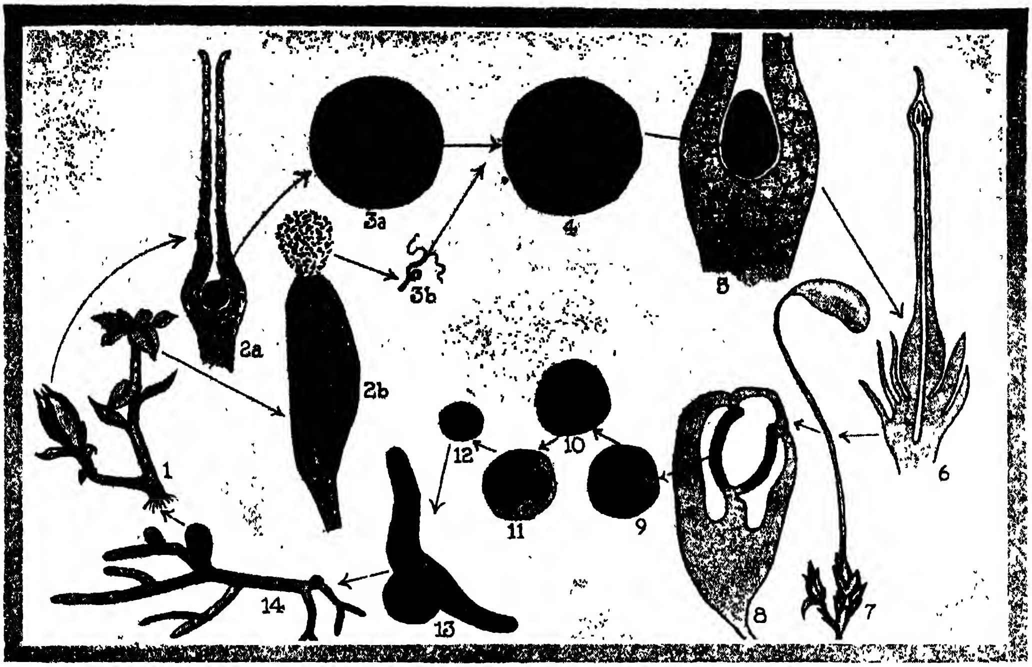
HOW MUCH DO YOU KNOW *about* MOSS?

This Story Will Tell You Some New Things about the Carpet of Plants on Which You Love to Set Your Foot

WE HAVE an old saying that all good things come in small packages. And there are a good many people who say that of mosses. For mosses are relatively small plants, although they may form a conspicuous part of our plant life. No matter where we may walk, whether it be through heavy woods or open fields, moss plants are always bending under our feet. They may grow on moist or dry soil; on bare rocks or on rocks covered with soil; on the bark of living trees or dead stumps; or even submerged in running streams or on the bottoms of ponds. They are especially abundant in cool, moist swamps where logs are rotting. Nothing is more beautiful to a lover of nature than a mat of moss carpeting the top of a half-rotted log or making a green floor in the woods.

But wherever it may grow, the moss plant always shows some shade of green, either light or dark, and is often brightened by the reds and yellows of its fruiting structures. The plants may have tiny stems and tiny leaves, but they never have real roots or flowers or seeds. These structures which we are calling leaves and stems are not true ones, as in our flowering plants, for they do not have the same construction. And that is something which we should remember. The form of the plants is variable. Some are slender plants, others resemble tiny fir or cedar trees, while still others are like the crested feathers of ostrich plumes.

The stems may be erect or prostrate, and branched or unbranched. In the tropical countries there are certain mosses which actually grow from three to six inches in height. These would look almost like giants compared with some that are so short that only



Here is a series of diagrams showing the whole life history of a moss through both the sexual and the asexual generations. We start with a male and a female shoot (1). At the top of the male shoot is formed the antheridium, or sperm case (2b), and at the top of the female shoot is formed the archegonium or egg case (2a). In the archegonium is an egg cell (3a) whose large nucleus receives and unites with a nucleus from the sperm (3b) which has swum to the archegonium from the antheridium. The two nuclei join (4) at the bottom of the archegonium; this is the end of the sexual generation and the beginning of the asexual generation. The new fusion nucleus grows and divides to make many new cells (5). At last it produces (6, 7) a capsule on a long stalk, which remains attached to the top of the female plant (7). Fig. 8 shows the capsule enlarged and its top cut so that we may see where the spores are formed—the two black areas. These spores (9, 10, 11, 12) begin the sexual generation once more. They finally fall to the ground; there they grow and produce the fine creeping green threads (13, 14) on which grow the erect sexual plants shown at 1.

a tiny tuft of leaves attracts your eye. The leaves vary in size, some measuring half an inch while others are too small to be seen easily. They are usually thick and flat, and change rather easily in appearance. We find that some leaves are rigid and stretched out in a very healthy manner. Others are shrunken and wrinkled, and lead us to feel that these plants are in a sickly condition.

Nature's Cool Green Carpet

If we are to have a complete knowledge of the moss plant, we must go to the woods or fields and pick a handful of a common moss. Most of us in our walks through open fields have come across carpets of a deep green moss looking very much like a thick velvet. Botanists call it "Polytrichum commune." "Polytrichum" (pô-lĭt′rĭ-kŭm) means that it has many hairs, and "commune" (kŏ-mū′nē) means that it is very common. "Polytrichum commune" is one of the best-known of all the thousands of mosses.

The Tiny Moss Plant

Let us pull some of this moss from its green, velvety carpet and look at its various parts. We see that it consists of erect stems, which may be branched or unbranched and which bear medium-sized leaves. Toward the very tops of many of the stems the leaves will be closer together and different in shape from the lower leaves, forming more or less of a crown. Inside this crown there are produced many clublike structures, small but quite distinct. In these structures, small cells, which are capable of swimming in water, are produced. Because some of these cells will unite with other larger cells, we call them sperm cells; and so this plant is a male plant.

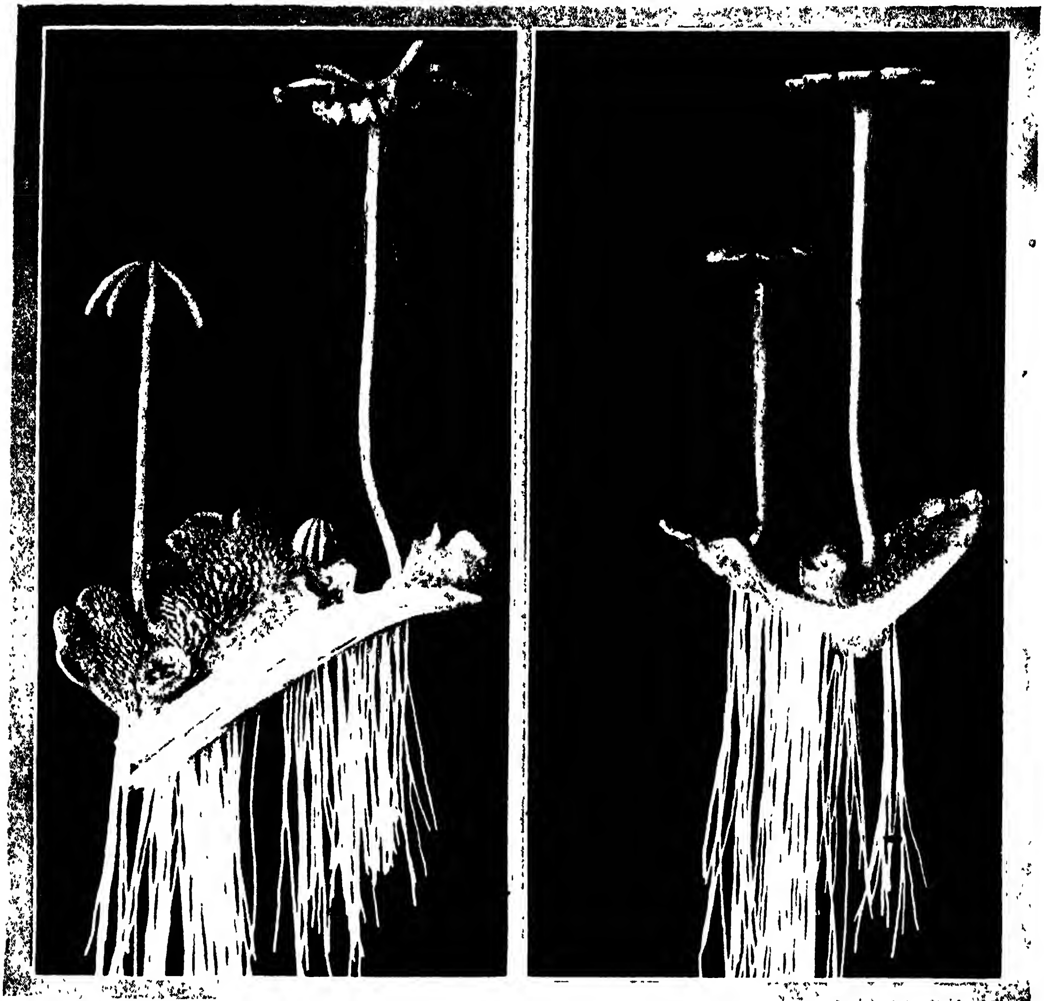


Photo by Field Museum

The liverwort is often mistaken for a true moss. The upright structures on the female plant at the left bear the bottle-shaped archegonia in which the egg cells are formed. The male plant at the right bears the sperm cases, or antheridia. The cup-shaped objects or cupules— on the plants contain little egglike bodies, or gemmae--tiny plants that break away and form new plants like the parents.

At the tops of the stems of other plants will be found groups of bottle-shaped structures, each one holding within it a single large cell. We call these egg cells, and it is only the female plants which produce them.

After rains or heavy dews the sperms are able to swim to the egg and unite with it. The uniting of two cells of different sizes is called "fertilization" (fûr′tĭ-lĭ-zā′shŭn), and because there are two kinds of cell needed, male and female, it is called "sexual reproduction." It occurs in some of the algae and fungi, but it is not so conspicuous in these as in moss plants. This type of reproduction is found in all the groups of the more complex plants.

The egg which has united with a sperm is called a fertilized egg, and it is usually only after an egg has been fertilized that it will develop. At first, it produces a long, slender, stemlike thread which is very noticeable. Indeed it stands up well above the general carpet of green that we usually call moss. At the upper end of this slender part we find an enlarged portion which is generally called the "capsule"; at its top is a cap.

So it is only the female plants of Polytrichum that develop the capsule with its complete covering. Usually the cap, which is covered with hairs, drops from the top of the capsule. Hence this moss is commonly called "hairy-cap." Inside the capsule are produced thousands of spores which are ready to tumble out when the capsules quiver and shake in the wind. These spores are not seeds, but as in the fungi they produce new moss plants.

And so there are really two alternating generations of moss plants. The one generation is the common plant as we see it, which has been produced by that simple structure which we have called the spore; the second began with the fertilized egg and eventually formed a capsule in which the spores were produced. We call the first generation the sexual generation because it ends with the union of the sperm and the egg. The second, which begins with the fertilized egg and ends with the spore, involves no union of cells and is therefore called the asexual (ā-sĕk'shû-ăl), or non-sexual, generation. All of our more complex types of plants have these two kinds of reproduction, usually alternating with each other

Though the hairy-cap moss and thousands of other mosses are green plants, another large group is not so green. All through the cool and cold regions, we can find swamps and bogs covered with a spongy, grayish-green carpet often many feet thick. It is a thrilling experience to walk upon a bog covered with these plants, for it shakes or quakes as we pass over it. This kind of moss is called sphagnum (sfăg'nŭm). If we dig down in such bogs, we can find old, dead sphagnum sometimes many feet under the surface. The buried plants do not decay completely, and when there is great pressure above, the sphagnum is pressed into tight layers of what we call "peat." This "peat," when cut and dried, is used in place of coal in many countries, although it never burns so well as coal.

When sphagnum plants are dried out, they are able to take up large quantities of liquids and hold them. So sphagnum can be used in emergencies in place of cotton. During the World Wars there were several kinds much used for surgical bandages. Frequently these plants are used as packing material for articles that must be kept moist.

There are certain mosslike plants which are frequently confused with the true mosses. They are rather dark green in color, and almost always are to be found in wetter places than mosses. Such plants have been called liverworts, for in the olden days they were used in medicines for ailments of the liver. Most of them lack some of the characteristics that are commonly associated with flowering plants. They do not have roots, but only fine hairs that take the place of roots. They do not have stems or flowers or seeds. Usually they are broad and flat and thin, clinging closely to the ground or rock or old log on which they happen to be growing. Their life history follows very closely that of the mosses, even though some of the structures which are produced may not seem to correspond.

These dainty little moss plants bear a name quite out of proportion to their size. They are called *Weisia viridula*.

Here we may see the tiny spore-bearing capsules that the female moss plants develop on the ends of delicate hair-like threads.

BOTANY

Reading Unit No. 15

NATURE'S LACE OF LIVING GREEN

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What ferns need for growth, 2–87
The life history of a fern, 2–87-90
The brown spots on the underside of fern leaves, 2–88
How ferns reproduce their kind, 2–88-89
Where we find most ferns, 2–90
Giant tree ferns, 2–90
How we use ferns, 2–91-92
The horsetails and club mosses, 2 92

Things to Think About

Where are the true stems of ferns found?
How are fern spores spread far and wide?
Where do ferns keep their sperms and eggs?
How are fern babies born?
What fern has leaves over twenty feet long?
In how many interesting ways are ferns used by man?
What fern relatives are used to make Christmas wreaths?
Why are "horsetails" so called?

Picture Hunt

What stage of a fern resembles a fiddlehead? 2–88
Which fern has uncovered sporangia? 2–88
Which stage of a fern is sexual; which is asexual? 2–89
In what period of the earth's history did giant tree ferns flourish? 2–90
Which fern is killed by the first frost of the year? 2–91
What fern is protected by law in Connecticut? 2-91

Leisure-time Activities

PROJECT NO. 1: Throw into a fire a small amount of Lycopodium powder—a product obtained from a club moss, 2–92.

PROJECT NO. 2: Place a few fern sporangia under the microscope while they are dry and see how they open, 2–88.

Summary Statement

Ferns love shady and moist places. They bear spores on the backs of their leaves. When the spores fall on suitable ground, they germinate into a flat prothallium, which bears sperms and eggs. Out of a prothallium comes a tiny, leafy fern which later develops fully into a fern. In this way ferns show alternation of generations.

Sometime when you have been walking through the woods you have probably come upon a great community of ferns, such as these. When ferns are hardy, and find just the place they like best to live in, they grow in great numbers and make a closely crowded community. The more delicate varieties seldom grow so closely crowded in temperate countries such as ours, though they may sometimes do so in the Tropics.

NATURE'S LACE *of* LIVING GREEN

Have You Ever Noticed the Little Round Spots on the Under Sides of Fern Leaves? Do You Know What They Are?

PERHAPS nowhere in the plant kingdom do we find so many graceful plants as we do among the ferns. Our forests, our hillsides, and even some of our swamps would look rather barren and forbidding without them. And many of the ferns are useful as well as beautiful.

There are certain conditions necessary for the development of ferns. They need the proper warmth, moisture, and shade, although the various kinds need different amounts. So we may find a goodly number of ferns thriving only in rocky places, forcing their roots through crevices in search of a little earth from which they may get mineral substances and water. Often this kind of fern is exposed to intense heat from the sun and does not grow to very large size. Others are to be found along damp hillsides or wet, rocky ravines moistened by the spray of falling water. Certain others seem to select open fields which may be rather dry and unshaded. In southern Florida one kind grows in water and is able to get along very well.

For the purpose of our study of the life history of the fern we could hardly do much better than to pick a common wild variety which many people call polypody (pŏl'ĭ-pō'dĭ). Thriving in woods and on cliffs, it does much to cover some of nature's bare spots. Very seldom does this plant reach a height of more than six inches. The leaves—sometimes called "fronds" because of their structure—are of light green and unfold early in spring, usually along in April. The uncoiling of the leaf is interesting to look at, and we often wonder how the fern plant can pack so much leaf in such a small bundle. These large leaves arise from a stout stem, called a "rhizome" (rī'zōm), which usually creeps just under the surface of the ground.

As the fronds of polypody grow old, their under sides are freely covered with brownish spots. In polypody these spots are free from any covering, but in ovary (ō′vâ-rĭ) ferns they have little structures which shade them

and protect them. If we take out our hand lens and examine one of these spots on the leaf of polypody, we find that it is made up of a number of brownish structures. And each of these brownish structures possesses a stalk which securely fastens it to the leaf. Botanists call these structures "sporangia (spô-răn′jĭ-ȧ), and each bears many spores, just as the capsule of the moss does. When the spores are ripe, the sporangium—the singular form of the word—breaks open and suddenly snaps back. During this snapping back most of the spores are thrown into the open. Then they are carried away by the winds. Each spore seems to be nothing more than a tiny spot of living matter. The number of spores produced by a single plant is vast, often running up into the millions. Fortunately for us, not all of these spores manage to develop, or it would not be long before we should be crowded off the surface of the earth. A large number are always lost because they finally come to rest where conditions are not favorable for their growth. For its best development the spore should settle down in some moist, shady place.

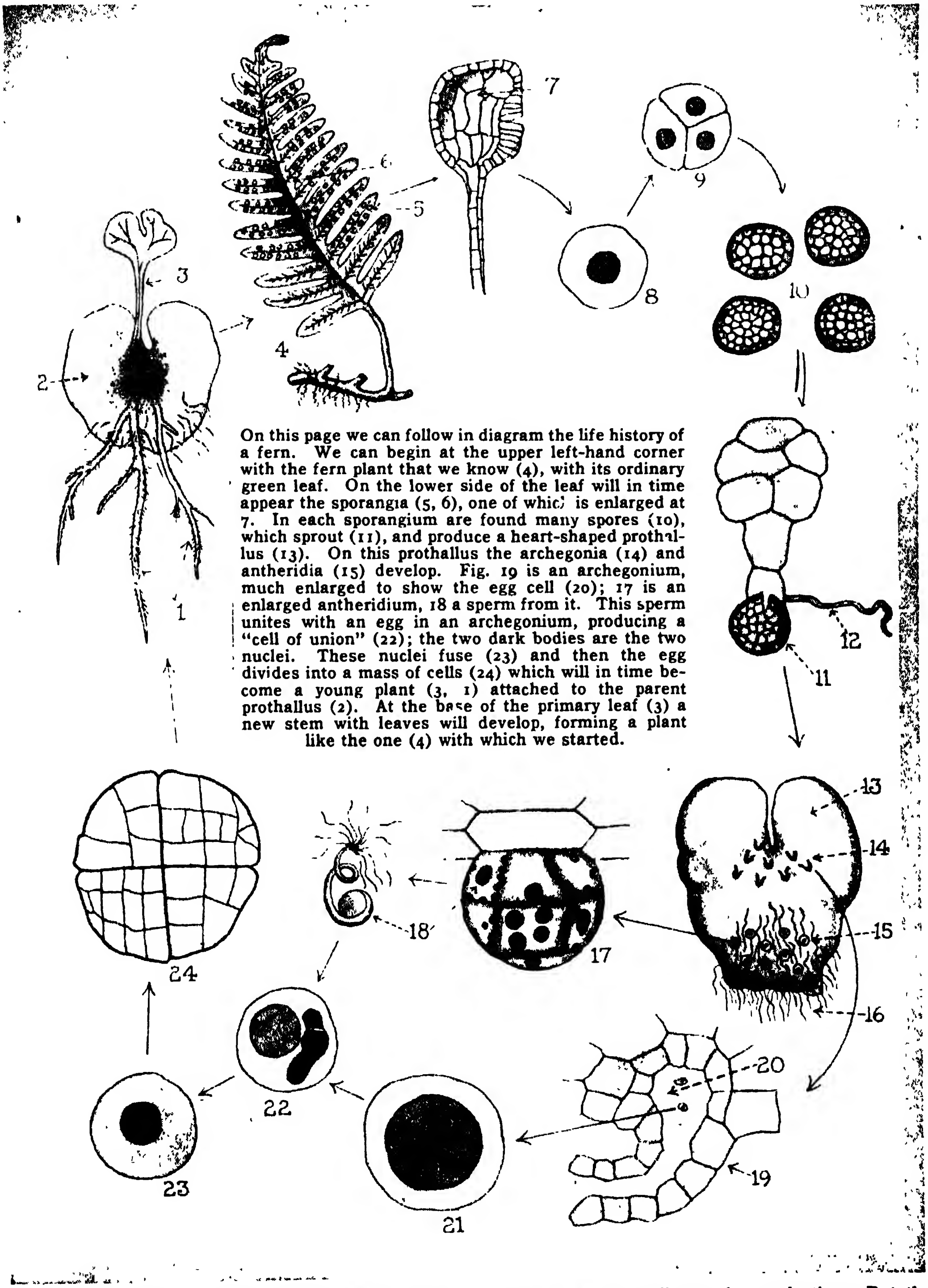
Photos by Cornelia Clarke and American Museum of Natural History

The tightly curled fern frond in the top picture is just beginning to unfold. When it has spread open and grown to its full size it will produce its spores in sporangia on its lower surface—either in large naked masses, as in the polypody shown in the lowest picture, or in long rows of little knoblike sporangia each covered by a protective outgrowth of the leaf, as in the fern shown in the middle picture.

How Fern Babies Are Born

In such a place the tiny speck of life begins development, not into the usual fern plant, but into a flat green structure. Such a structure is roughly heart-shaped, and it grasps the ground tightly by means of tiny hairs. One of these heart-shaped structures is called a "prothallus" (prô-thăl′ŭs)—from a Greek word meaning "in place of a young shoot." It can sometimes be seen growing underneath old fern plants. If we examine the under surface of a prothallus with our hand lens, we find both kinds of structures in which egg cells and sperm cells are produced. They are very small, and we have to examine carefully. As in the moss plants, the eggs are fertilized by the sperm cells—that is, the two join to make one cell. So far as we know, the sperm cells always journey to the egg cells in water.

It is not long after fertilization (fûr′tĭ-lĭ-zā′shŭn) that a new plant appears, usually only one to a prothallus; this is the familiar fern that we know. The new plant is entirely dependent for its food on the small prothallus which bears it, and remains so, as a rule, for the first few months of its life. Little by little the plant grows, first sending a small root into the soil and later thrusting a tiny leaf toward the light. From then on,



On this page we can follow in diagram the life history of a fern. We can begin at the upper left-hand corner with the fern plant that we know (4), with its ordinary green leaf. On the lower side of the leaf will in time appear the sporangia (5, 6), one of which is enlarged at 7. In each sporangium are found many spores (10), which sprout (11), and produce a heart-shaped prothallus (13). On this prothallus the archegonia (14) and antheridia (15) develop. Fig. 19 is an archegonium, much enlarged to show the egg cell (20); 17 is an enlarged antheridium, 18 a sperm from it. This sperm unites with an egg in an archegonium, producing a "cell of union" (22); the two dark bodies are the two nuclei. These nuclei fuse (23) and then the egg divides into a mass of cells (24) which will in time become a young plant (3, 1) attached to the parent prothallus (2). At the base of the primary leaf (3) a new stem with leaves will develop, forming a plant like the one (4) with which we started.

If you follow these pictures you will see that the ferns, like the mosses, have alternating sexual and asexual generations. The prothallus, the little flat plant most of us never notice, produces egg and sperm, which unite in what we call sexual reproduction. But the big leafy plant that the word "fern" brings to mind produces only spores, which are not the product of two united cells and are therefore asexual.

the young fern plant provides for itself, while the prothallus withers and dies. Gradually the baby plant grows larger and larger until it eventually becomes as large and beautiful as the original plant that produced the spores carried by the wind.

Nearly all the ferns of North America have underground stems and finely divided leaves, on the backs of which are formed groups of sporangia. These sporangia are sometimes on the veins of the fronds and sometimes only on the margins of them. A few, such as the "sensitive fern" and "grape fern," have not entrusted the production of spores to all the leaves, but have special leaves which do nothing but develop spores.

Photo by N. Y. Botanical Garden

Here is a very beautiful large tree fern growing in a greenhouse at the New York Botanical Garden. This kind of fern grows out of doors only in very warm climates. So nowadays we find it only in the Tropics. But ages ago, before man appeared on the earth—before the coming of even our familiar seed-bearing plants—the earth's climate was warmer than it is now, and giant tree ferns flourished in many parts of the world. You may see an imaginary picture of one of those old fern jungles in an earlier chapter of this story.

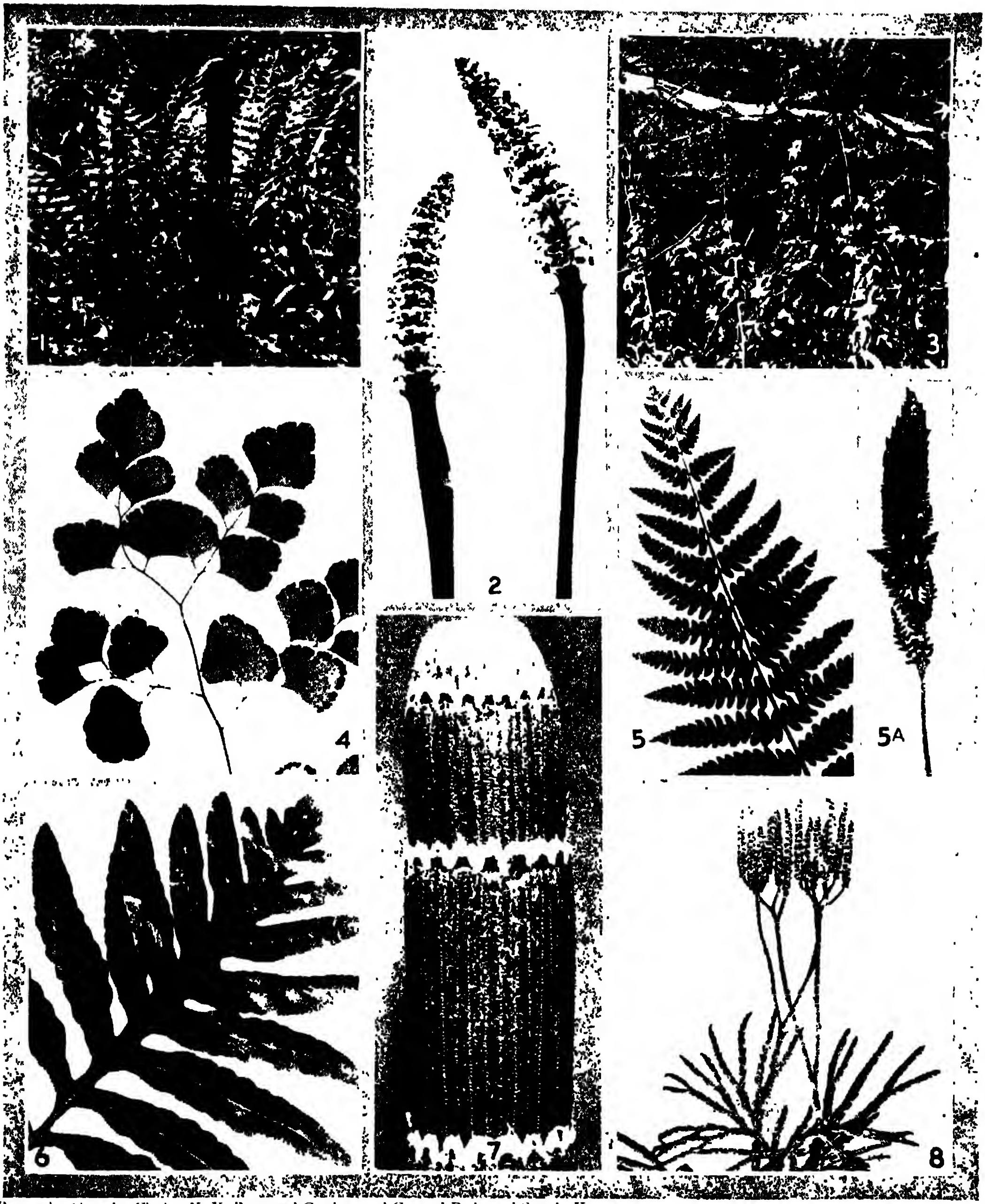
But not all grow in this same general way The development of some ferns has been rather unusual. Some have developed the climbing habit, and see the world from a higher level. In Florida there are other ferns to be found which have lost all communication with the ground during their entire life. As we go farther south, we may see hundreds of plants which never set foot on the soil; all their life is spent in the foliage at the tops of tropical forests.

Though we have scores of different kinds of ferns in the Temperate Zones, such as the chain fern and the shield fern and polypody, the true home of ferns is still in the Tropics. There they form a beautiful part of the growth in the moist, hot regions. Really, when we try to picture the Tropics we should always find a place for ferns in it. And in this true home of the fern, we see that the most handsome and stately ones are the tree ferns. These are very conspicuous in Brazil, Australia, the East Indies, and tropical Africa.

The tree ferns have great trunks, often fuzzy-haired, with a crowd of huge fronds at the top. There are no branches, such as we find in many other trees, and the fronds, which may be fifteen or twenty feet long, are always finely divided into hundreds of subdivisions, or pinnae (pĭn'ē). No more beautiful sight can be found in a tropical forest than these kings of the fern world. You may sometimes see them, on a small scale, trying to grow in the florist's window.

Although ferns are very beautiful, they do not furnish by any means so many useful things to man as do the flowering plants. Two or three kinds are eaten as young greens in Panama, and in the Pacific islands there is one kind which stores enough starch in its rhizome to furnish a coarse food for the natives.

Of all the different ferns which are supposed to be good for medicine, only the male



Photos by Cornelia Clarke, N. Y. Botanical Garden, and General Biological Supply House

Here is a page of ferns and fern allies which should help us to know these fascinating plants better. All the varieties shown grow in the lands of the Temperate Zone. The first picture (1) is a cinnamon fern, *Osmunda cinnamonia;* 5A shows a fertile leaf and 5 a sterile leaf of this fern. Picture 3 is the climbing fern, *Lygodium palmatum*. It has five-fingered, palm-shaped leaves, and does not look much like other ferns. It is so rare that a law was passed in Connecticut to protect it. Picture 4 is the delicate maidenhair fern, which grows in moist, shady places in most parts of the United States and Canada. It has a black, shiny stem and grows its spore cases on the under margin of a frond. Picture 6 is the sensitive fern, *Onoclea sensibilis,* which doubtless owes its name to the fact that it droops with the first frost. This fern is common from Newfoundland to Florida. Its fertile frond rolls into a round ball-like form around the spore case. And now for the fern allies: first, the horsetail, which is seen in full flower in 2, and with its jointed stalk enlarged fifteen times in 7. At 8 is another of the fern allies, *Lycopodium complanatum,* one of the interesting Lycopodium family of which you may read in this story.

fern is really worth much. It is widely used to kill tapeworms. A few Philippine ferns are used by the natives for snake bites or for a stomach ache, but on the whole ferns are not of much account for medicine.

How We Use Fern Fibers

Even if ferns are not much good for food or medicine, many of them yield good fibers. Some are used for making baskets, hats, and even clothes in the Pacific islands, and to a slighter extent in tropical America. A few in the Philippines are employed to make beautiful cigarette cases, and one, known as the "diliman," furnishes a rope that does not rot in sea water, and can therefore be used in making fish traps and nets.

But the ferns are best known as ornamental plants. For their graceful, feathery foliage, over two hundred kinds are grown in greenhouses. Perhaps of all these the Boston fern is the easiest to grow, even in an ordinary room. All of its ancestors came from moist tropical forests, but this widely cultivated house plant is a variety which was discovered in a Boston greenhouse about 1895.

The Fern's Near Kin

There are a few plants which seem, from their structure and way of life, to belong to the great fern tribe but which are different enough from true ferns to be known as "fern allies." They are allied, or related, to the ferns, but they cannot be classed as true ferns because one group of them seems to have no leaves, while the other does not bear its spores in the leaves.

At Christmas time your window wreath is very likely to be made of ground pine, or Lycopodium (lī'kō-pō'dĭ-ŭm)—a word that means "wolf foot." It is the best-known of those fern allies that bear their spores on the leaves. It has tiny, scalelike leaves pressed closely against the stem, which often trails along the ground. It is this trailing habit and its evergreen foliage which makes ground pine so popular for Christmas wreaths.

There are many different kinds of Lycopodiums, but all of them bear their spores in a single sporangium which is situated at the base of the leaf. Such leaves have been called sporophylls (spō'rō-fĭl). The spores will develop into new plants if they have the proper conditions, but of course most of them die, as is the case with the ferns. It is these spores that give us Lycopodium powder. Lycopodium powder makes a brilliant blaze when touched off by a spark, but will not burn long enough to set anything afire. Because of this it is widely used for making fireworks, for making "fires" in the theater, and for setting off "lightning" in the movies. The spores of this fern ally thus give us a fire that is mostly flash, with no smoke.

The Curious "Horsetails"

Just as strange as ground pines are the "horsetails" and "scouring rushes," plants which look as if they had no leaves at all. They were given the name of Equisetum (ĕk'wĭ-sē'tŭm) because that name exactly describes them--"equus" meaning "horse" in Latin, and "setum," a "tail." We can find them on railway embankments or in marshy places, and we can tell them at once by their likeness to a horse's tail. We can also see, if we look sharply, that their small leaves are so well hidden as to make us think at first glance that the strange plants have no leaves at all.

The stems are usually green, often grooved or roughened, and usually perfectly rigid and upright. At intervals the stem will send out a tier of small branches, almost threadlike but still rather stiff. At the base of each tier of branches, if we have keen eyes, we may see tiny scale leaves, which are tightly pressed against the main stem and practically useless to the plant.

The Horsetail's Strange Little Cone

Perhaps the most interesting thing about the Equisetum is the way in which it bears its spores. Like all ferns and fern allies, it has no flowers. But the Equisetum does have its spores in a conelike structure not very different in appearance from a tiny pine cone—and the pine is a true seed-bearing plant. We may find these conelike structures at the top of some of the horsetails, and on special stems in others.

BOTANY

Reading Unit
No. 16

WHAT IS A CONIFER?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Things to Think About

What is paper made from?
In what structures do we find the sperms and eggs of conifers?
Why is it advantageous for conifers to produce a great deal of pollen?
What causes "knots" in the wood of conifers?
Why are evergreen holly and rhododendrons not considered conifers?
What close relatives of conifers, now scarce, used to cover the earth?

Picture Hunt

On which surface of a pine cone scale are the seeds? 2 94
What do male cones produce? 2–95
How long are the cones of the giant redwood tree? 2 96
What part of a pine is eaten by man? 2 97
What part of the United States has the best conifer wood? 2–98

Leisure-time Activities

PROJECT NO. 1: To find seeds in pine or spruce cones, pry open the scales and examine them, 2 95.
PROJECT NO. 2: To study the seed of a pine, get some "pinon nuts" sold in nut stores and carefully cut the nut meat, exposing the sticklike embryo in the center of the edible endosperm, 2–97.

Summary Statement

Most conifers keep their leaves the year round, and provide a valuable soft wood much used in carpentry and paper making. They usually have scaly cones, which contain the seeds, but trees like the juniper and the yew have fleshy fruits instead of cones.

Photo by N. Y. Botanical Garden

The female cone is the one we usually notice on a conifer, for while the male cone is only half an inch or so in length, the female cone is much larger. It bears the eggs and later the seeds; they are attached at the base of the scales, but on the upper surface, not on the lower as the pollen sacs are.

WHAT IS *a* CONIFER?

The Botanist Gives the Name to a Tree That Bears Cones for Flowers, and Here You May Learn How the Cones Do Their Work

WHEN the early Christians first went into Northern Europe, they found the barbarians there using a beautiful evergreen tree to celebrate the birthday of a pagan god. The Christians had no use for the pagan god, but they liked the pretty custom of using the evergreen tree. So they made it their own. And that is why we still use that old custom whenever we put up a Christmas tree.

Of course we use an evergreen tree because it is the only one that is usually green all through the bleak winter. Besides the kinds of evergreen we use for Christmas, there are several hundred other kinds scattered over the earth. They are common in the cooler regions, where their dark green foliage often makes a beautiful contrast in the landscape. But although we call them evergreens, we must not suppose that their leaves never fall. All of them lose their leaves, and some have very special ways of doing it. It is something other than their winter dress which makes us put all of these trees in one class; and in a moment we shall see what that is.

With their evergreen habit these trees have two other features, even more important than the fact that they give us Christmas trees. Nearly all of them give us soft wood, plentifully supplied with gummy resin. In some kinds the wood is so soft that it can be turned easily into pulp; and from that pulp is made the rather coarse paper on which most newspapers and cheap magazines are printed. Your corner newsdealer may not know what a "pulp magazine" is, but every printer and editor knows it is a cheap one, printed on pulpwood paper.

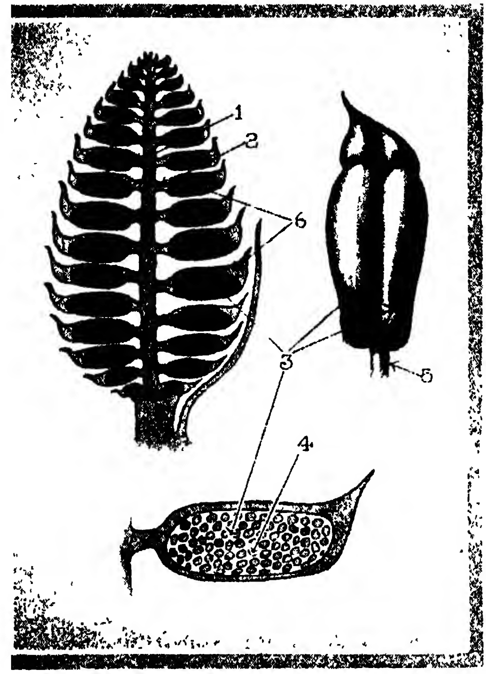
The resin in the wood is used in enormous quantities to make turpentine and a kind of tar. When simply dried, it makes rather cloudy masses of a sticky material which may be used to "rosin" a violin bow, and to put on your hands to keep them from slipping.

Many thousands of years ago some of the evergreens, long since known only by the remains we find in rocks, produced enormous quantities of resin. Probably they produced this when their bark was injured in some way; it is the same thing that makes spruce trees give us spruce gum to-day. The resin from these ancient trees settled in

lumps which we now dig up and prize very much. For that buried resin, still plentiful around the Baltic Sea, is the amber from which pipestems and many beautiful ornaments are made.

But perhaps you are beginning to wonder what it is that makes us place all these trees in one group. Let us see about that.

In our story of the ferns and fern allies, we said that small conelike structures are found in some of them, and that each of these consists of a number of sporophylls (spō'rō-fĭl), or spore-bearing leaves. Now it happens that in a group of those plants there are two kinds of spores produced, of course in different sporangia (spô-răn'jĭ-ȧ), or spore cases. These two kinds of spores will differ usually in size and number—many being small and few being large. When these spores develop, the large ones produce structures containing egg cells, while the small ones produce structures with sperm cells. So in ferns and fern allies, reproduction is carried on by the final union of the two kinds of spores.



In the evergreens, pollen is produced in small, inconspicuous cones which usually grow in clusters. The large diagram shows one such male cone cut lengthwise; 1 is its axis, or main stem: 2, the stalk of a scale; 6, the scale itself. The upper arrow of 6 points to the dark mass of the two pollen sacs which hang from the bottom of each scale. These sacs are shown enlarged at the right (3); in the diagram below we can see the pollen grains (4) within such a sac.

All of us are quite familiar with the pine tree, especially the white pine, for it is a very common plant in our woods. Upon it are borne structures which we call cones, usually of two sizes—the one, when mature, reaching a length of about two inches, while the other is a half inch in length. Even though there are usually many more of the small ones than the large ones, they are sometimes very difficult to find.

The large cones are interesting, and we must examine them closely. As we tear one apart, we notice that it is composed of scalelike structures, rather woody, which are sporophylls. In the evergreens we have changed the name of this kind of sporophyll to carpel. Now at the base of each one of these carpels, there are two conspicuous structures. Really they are sporangia, but since they are more complex in structure than ordinary sporangia they are called ovules (ō'vūl). And it is inside each ovule that four of the large kind of spores are produced. Curiously enough, only one of these spores develops, and that development takes place inside the ovule and completely out of sight. So again, as this kind of spore develops, it produces an egg cell. It is really a very ingenious way for the plant to provide protection for the egg cell in its later development. The ovule is not completely closed, but has a very small opening at the lower end. So here in this cone we have a number of carpels, each one bearing two naked ovules—naked because they have no complete covering.

The botanists have a word for this kind of plant; they call it a "gymnosperm," (jĭm'nō-spûrm)—a word which comes from two Greek words meaning "naked seed." These plants, then, belong to that small class having a naked seed, no ovary, and no real fruit—the gymnosperms. And because they usually bear their ovules in some sort of cone they are often called the "conifers" (kō'nĭ-fẽr), which simply means "cone-bearing."

Now look at the small cones. Are they young cones of the kind that we have already

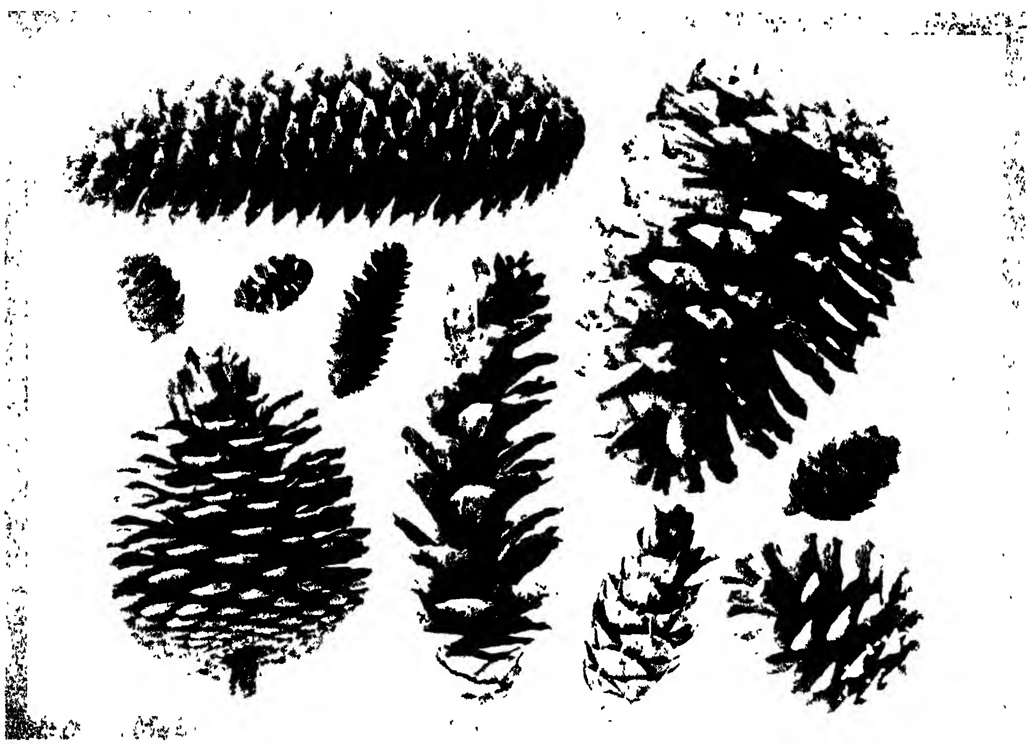


Photo by Cornelia Clarke

There are many sorts of cones. Some of them weigh several pounds; they may be two feet long or six inches broad. On the other hand, the giant redwood, largest of the conifers, bears cones no bigger than the end joint of your thumb. Again, some are strong and hard, like the one in the upper right-hand corner; others are almost papery, like the long one in the upper left-hand corner.

seen, or are they completely different? They, too, are composed of little scalelike structures—sporophylls—which have been called stamens (stā′mĕn). For if we examine one of these stamens, we soon find that on the lower surface are two little sacs. Frequently these sacs, or sporangia, are quite yellow in color. In the mature stamen, each sporangium, or pollen sac, is a plump storehouse very full of little globular structures with little wings, resembling yellow particles of dust. These fine particles with wings are called pollen grains, and they have formed from the small spores which were originally produced in the sporangia.

The Powdery Pollen of the Evergreens

The pollen is especially powdery, and thus suited to be carried by the wind. For the evergreens have no other way of conveying pollen from the small or male cones to the large or female cones except by the breezes. Of course much pollen is lost because the wind cannot carry each grain to the proper place. But the evergreens all produce large quantities of the fine yellow dust, and every spring you may see clouds of it coming from the pine woods. It floats away on the wind, often quite uselessly, for miles. But if a rain catches it, there may be what some people used to think was a shower of sulphur. And it does look very much like sulphur. But always some pollen is carried from the small cones to the large ones.

What Happens to the Pollen Grain

What happens to the pollen grain once it has been carried to those large cones? At about the time that the pollen is carried, the carpels of the cone become separated and allow the pollen to sift down between them before closing again. Usually at least one pollen grain will land at the opening of each ovule and begin its development and growth. When it begins its growth, it looks in a general way like a small seed, but of course its

Photo by Nature Magazine

We do not usually think of the pine as a food-bearing tree, but here, spread out under Italian skies, is a fine harvest of pine cones. The cones have been collected a little green and spread out to ripen in the sun. The harvesters have done this so that the seeds, the delicious pine nuts, may be easily shaken out and gathered; for if the cones were allowed to ripen on the trees the nuts would fall out and scatter far and wide. There are two kinds of pine in Europe and one in America which produce edible seeds.

structure is not the same. It pushes a small tube into the ovule, and while it is doing so, two sperms are formed in it. When the tube nears the egg cell, the sperms are released and one of them unites with the egg cell.

The Development of the Young Plant

From the fertilized egg there develops the young plant. The entire ovule becomes changed and turns into a sac, usually covered by a heavy, stony coat. Some of these seeds are edible, especially the "stone pines" of Europe and the ones called "piñon (pē-nyōn′) nuts" in the West. We may find them in the markets of Central Europe, and in our Southwest and Mexico. The seeds are sweet and delicious, and are sometimes put into candies.

So we see that the seed is a wonderful little structure. In it—in the ovule condition—the spores have been produced and developed. Eventually we find the ovule changing to a seed within which is developed a complete little plant with a store of food. It is little wonder that so many of our plants have developed such a means of reproduction, for it is an excellent device for producing sound offspring.

Nearly all our conifers have only one central trunk, which never splits up into branches, like an elm or maple, but extends from the ground straight up to the growing tip. That may be a long way up in some of our western pines; in the California redwood it is sometimes over three hundred feet. It is this habit of growth, called "excurrent" by the botanists, which makes an evergreen forest such a majestic sight.

Although they have undivided trunks, conifers have many branches, arranged in tiers or "whorls" (hwûrl). In the younger trees there is one whorl for each year of age. Each season a new crop of young branches starts growing at the same time that the tip starts pushing upward again. The branches which develop year by year are extensive enough in trees that grow in the open, but in the forest the lower ones are gradually killed off, because their leaves cannot get enough light, as the trees around grow higher and denser. The withered stumps of these dead branches, covered finally by bark and wood, make up the "knots" that we find in coniferous (kō-nĭf′ẽr-ŭs) timber.

Even though the wood is not hard—it is

Photo by American Lumberman

This is the fate of many a magnificent pine which has grown long years to reach its proud height. In the Northwest it is no uncommon sight to see a single giant log reaching across a whole freight car, as it does here. Probably all the other cars in the picture hold sections of the same great tree.

often called "soft wood" by the lumberman—it is so easy to work that there is great demand for it. In the northwestern states, which contain some of the greatest coniferous forests in the world, you may often see whole trains loaded with logs of the redwood or Douglas fir. So big are these logs that frequently each car will hold only two or three gigantic logs, and sometimes only one. From a single undivided trunk many feet in diameter it is often possible to cut over two thousand board feet of lumber.

How to Group American Conifers

We can group most of our American conifers according to the way in which their leaves are arranged and the way in which they are shed. Either the leaves are somewhat needle-shaped, or they are small and scalelike. When they are scalelike they are usually pressed so tightly against their twigs that we are likely to think we have a mere scaly twig instead of one that is covered with small, scalelike leaves, such as we find in the arbor vitae and in most junipers.

The needle-shaped leaves are well known in pines, and in fact we call these leaves "pine needles." They are more like slender green needles than are the leaves of any other evergreen, and they always have a sheath around the base. Sometimes the sheath will inclose only two needles, but in the common white pine it holds five.

The spruce, from which we get pulpwood, and the firs, from which we get most of our Christmas trees, both have needle-shaped leaves that are mostly shorter than pine leaves and look much less like needles. In the firs, the needles are nearly flat, and they may hang on for several years, only a few dropping off at a time. But most spruce leaves are somewhat four-sided, and they have a joint at the base which makes them fall off more easily than the leaves of any other evergreen. It is this which makes spruces poor Christmas trees and firs good

ones, for the leaves of spruce will all fall off in the heat of the room, while fir leaves cling on even when they have grown brown and dry.

There are two or three kinds of coniferous trees that cannot be called evergreens at all, because they drop all their leaves each autumn. The larch, or tamarack, so common in our northern bogs, and the cypress of our southern swamps, do this; so do some of the conifers in Asia and Australia. On the other hand, we find some plants, such as holly and certain rhododendrons, which have some green leaves all the year and are therefore "evergreen." They are not conifers, however, because other traits show clearly that they belong to an altogether different group of plants.

Conifers That Bear No Cones

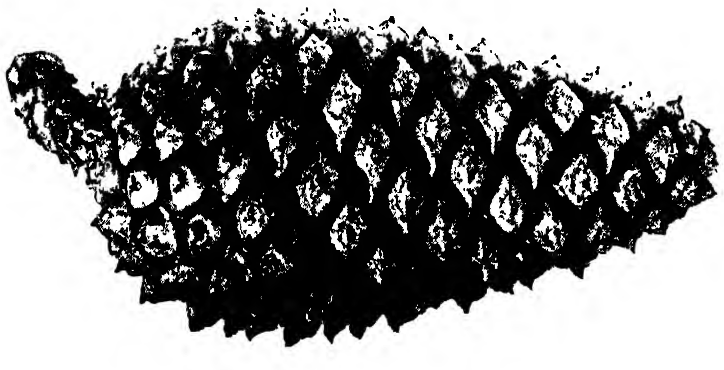
So many kinds of conifers have been developed that it is hard to fit them all exactly into their right places. Some of them have, besides queer, scalelike leaves, certain curious fruiting structures which we cannot call cones. In fact, these are called "juniper berries" in the juniper; and in the yew we find bright red or yellow berries that do not look in the least like the cones of a spruce, fir, pine, or hemlock. Instead of having male and female flowers on the same tree, the yews and their relatives have them on different trees.

But however much the evergreens may vary, there is one thing that is always the same in them. No matter what curious habits they may have developed, these plants always have simple, undivided leaves without any marginal teeth. In this way, they are different from their closest relatives, the cycads (sī'kăd), which have leaves so much divided that they look a good deal like ferns. Usually the cycads have their leaves in a crown at the end of a stout trunk, which looks more like the stem of a tree fern than like that of any flowering plant. Long ago there were many kinds of these trees, and they formed the chief vegetation of the earth, but now they have dwindled to only a few species, all found in the Tropics.

Most of us have seen the leaves of one of these ancient, fernlike plants many times, and we may have heard it called "sago palm." It is not a palm at all, but a true gymnosperm, with naked seeds between cone scales. It has long, glossy, evergreen leaves, with many leaflets, each ending in a tiny prickle. These leaflets are so arranged that the whole leaf looks like a gigantic stiff feather. Its only use is as a funeral decoration, in which we often see two leaves crossed and tied with a ribbon. The "sago palm" got its name from the fact that in its home in Java the natives get a sort of sago or starch from its trunk, and also from the fact that the tree looks a little like some of the palms.

In Florida there is another sort of cycad which the Seminole Indians called "coontie." From the half-buried trunk of it they used to get a vast amount of starch, which they fashioned into very nutritious cakes.

So cycads interest us because they represent the remains of a fast-dwindling race of plants. Once they clothed vast areas of the earth's surface, but now they cover only limited and scattered regions.



BOTANY

Reading Unit No. 17

WHY DOES A PLANT HAVE FLOWERS?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why flowers are important to plant life, 2–101-4
The structure of flowers, 2–101-4
The sexual parts of a flower, 2–102
Differences in flowers, 2-102-4
How baby plants are formed, 2–104

Things to Think About

What do sepals do for the flower?
Why are petals often colored?
What flowers have no corolla?
Where are pollen grains made in plants?
Where are seeds formed in a plant?
What is meant by "complete" and "incomplete" flowers?
What parts of a flower are absolutely necessary to it?
What happens in a flower after fertilization?

Picture Hunt

What conclusion can you draw after studying this picture? 2-101
What three parts make up the pistil? 2–102
What is found in the flower ovary? 2–103
What is another name for anther? 2-103

Related Material

Why must some flowers attract insects? 2-104
Why do not grasses have petals? 2-111-13
What happens to pollen on a stigma? 2-108

Leisure-time Activities

PROJECT NO. 1: To learn the parts of a flower, take apart a sweet-pea flower, 2-103.

Summary Statement

Flowers attract us because of their beauty; but they are really designed to attract insects. The important part of the flower is shielded by two outer envelopes, the calyx and the corolla. The stamens bear the pollen grains, and the pistil bears the ovules which contain the eggs of the plant. Unless the male cells of a pollen grain unite with the eggs in the ovules, no seeds will develop. Insects help in this union.

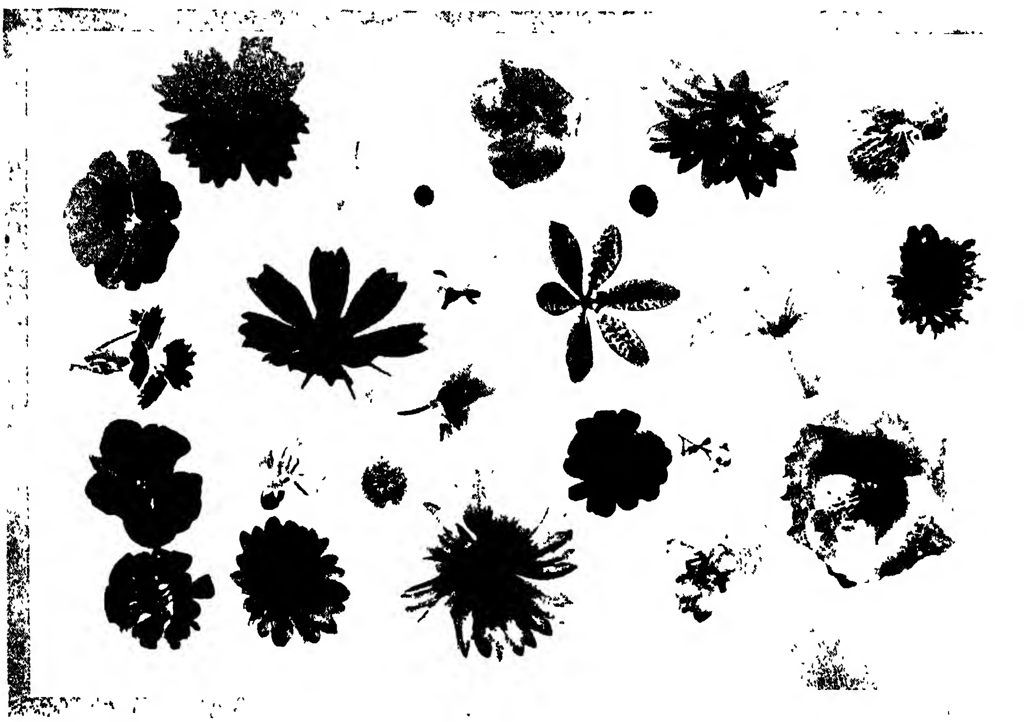


Photo by Cornelia Clarke

One of the marvels of Nature is the variety of flowers she has developed through the ages. Even in a picture such as this, in which we can see only a few kinds and those without any of their countless shifting colors, we can still get an inkling of the multitude and beauty of flower shapes. Yet these are only a few of the varieties that all of us see growing around us so commonly that we have come to take them for granted.

WHY DOES *a* PLANT HAVE FLOWERS?

Not at All to Delight Our Eyes and Nostrils, but for Far More Important Ends

A GREAT many of the plants in our gardens and in our fields bear flowers. Many of the flowers are very conspicuous and attract our attention at once. Who can wander through fields and woods in the springtime and not notice the yellow dandelion flowers, or the devil's paint brush showing its pretty colors, or the Dutchman's-breeches, with its curiously shaped flowers almost hidden from our sight?

There are still some people who seem to think that flowers are produced merely for their beauty and pleasant odors. We are fortunate indeed to have so many which are sweet and beautiful. But we must give up any idea that they are produced just for us to enjoy. Flowers developed long before any man existed upon this earth, and they serve a purpose far more important than our mere delight.

In order to understand the structure of a flower, and to see what some of its parts may develop into, let us select a flower which is well known to many of us, the common pea. In this flower we can see the parts which are to be seen in most flowers. But we must remember always that the size and shape and number of the parts in other flowers that we know may be different from those of the pea.

Let us, then, pick a pea flower from a plant and pull it to pieces as we might pull

"petals" from a daisy. Around the base of this simple pea flower we find five green structures which remind us very much of leaves. Each one of these is called a sepal (sē′păl). Many flowers have sepals, and often there are more than five. In some kinds of flowers the sepals are joined together, while in others they are separate. When the flowers are still in the bud, the sepals usually act as a covering over the other parts of the young flower. Taken together, the sepals of the flower are called the "calyx" (kā′lĭks), from the Greek word meaning "shell" or "covering."

Just inside the sepals of the pea flower we find five more structures very irregular in shape and size. These are petals. They are what are commonly called the "flower," though of course they form only a part of it. In different kinds of peas the petals may have different colors, often of very delicate shades.

There is a great variety of colors, shapes, and sizes in the petals of different flowers. Especially in those flowers which attract insects do we generally find brilliant colors of many hues. Frequently the petals secrete, or make, a sugary liquid called "nectar," which may be used by insects as food.

The "Little Crown" of the Pea

All together the petals of the pea flower make up what we call the "corolla" (kŏ-rŏl′ȧ), or "little crown." To be sure, there are many flowers that do not have a corolla. The flowers of grasses have none, and neither do the flowers of oaks and hickories and some of the maples.

Just within the corolla of the pea flower we find a tube with nine knob-shaped structures at the top, and also a single, slender stalk with a knob-shaped structure at its top. These seem to grow right out of the bottom of the flower. They are called stamens (stā′mĕn), and they are producers of pollen. So in our pea flower we have ten stamens, nine of which have grown together, with one left all by itself. The lower, threadlike portion of each stamen is called a filament (fĭl′ȧ-mĕnt), and at its tip it always has a tiny knob called the "anther" (ăn′thēr). It is in the anther that the pollen grains are formed.

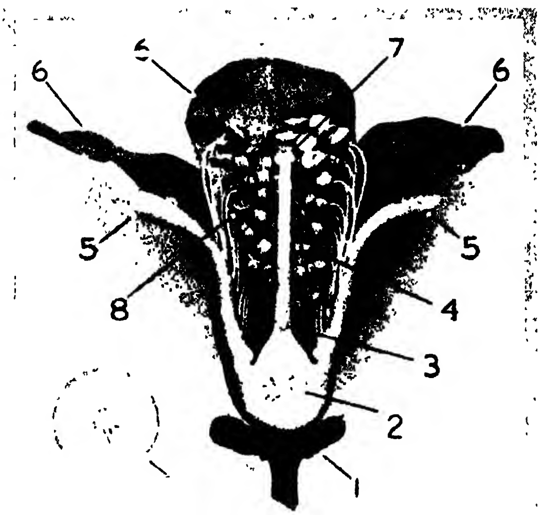


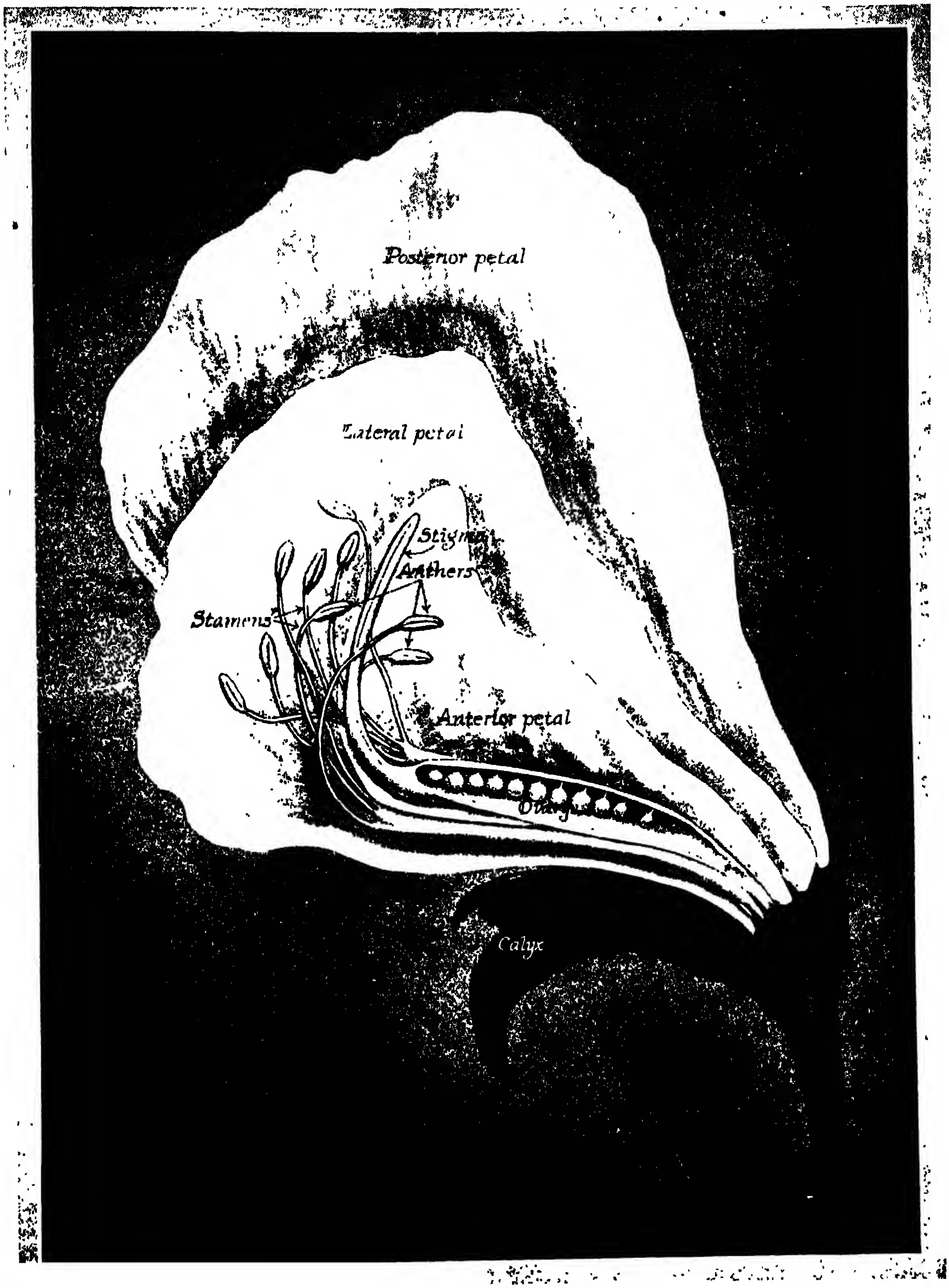
Photo by Field Museum

This is a pomegranate flower enlarged and cut lengthwise. The parts are: 1. Stem, which holds the flower. 2, ovary; 3, style; 7, stigma—the three parts that make up the pistil. 4, anther, and 8, filament, go to make up one of the many stamens. 5. Calyx. 6. Petals of the corolla. The diagram at the lower left is the ovary cut across to show the ovules in it.

In some flowers we have more or fewer than five stamens. They are far less showy than the petals, but are far more important—more important because they form the male part of the plant.

Right at the center of the pea flower, as in most flowers, is a slender organ called the pistil (pĭs′tĭl). We see it pointing right toward us as we look into the flower. The pistil is often called the female part of the flower. In the pea we find that it consists of three parts: the swollen base called the ovary (ō′vȧ-rĭ), the elongated part called the style, and the branching tip called the stigma (stĭg′mȧ). It is in the pistil that the ovules (ō′vūl) develop into seeds.

Flowers may show a great deal of variation. In the wild rose, for instance, the sepals shelter the bud, the petals give color, the stamens produce pollen, the pistils form and protect the young ovules and seeds. The wild rose bears a "complete" or "perfect" flower, since the blossom has all these parts. There are many other plants with complete flowers, but also many with incom-



Here is a sweet-pea flower cut lengthwise, with the petals labeled "posterior," or back, "lateral," or side, and "anterior," or front; the complete anterior petal is really two petals fused along one side to make an envelope around the stamens and pistil. Nine of the ten stamens show, each tipped with its anther, or pollen case. In the very center of the flower is the pistil. Pollen falls on its sticky stigma, and the pollen tube grows down through the style to fertilize the ovules in the ovary, which becomes the ripened pod.

plete ones. Some of them have no petals. Some, like the willows and the grasses, have neither petals nor sepals. Others have all the stamens in one set of flowers and all the pistils in another set, as is the case in our familiar Indian corn, which has its ovules and pistils in the ear and its stamens with pollen in the tassel. There are thousands of varieties of seed-bearing plants, with many different characteristics. But in every variety there are always stamens which develop the pollen and pistils which bear the seeds and form fruit.

The flowers are developed by plants to take care of reproduction. And as has already been said, the stamens and the pistils are the necessary parts of the flower, while the sepals and petals are helpful aids.

In what exact way do the stamens and pistils act? It is in the anthers of the stamens that the pollen grains are borne. In our pea flower there are ten anthers producing pollen. The pollen grains, when they develop, will eventually produce sperm, or male, cells. It is within the thick layers of the ovules borne by the ovary that the egg, or female, cells are produced. After the pollen is carried to the stigma of a pistil, it there begins to develop and grows down to the ovule. It is in the ovule that an egg and sperm unite in the process which is called fertilization (fûr'tĭ-lĭ-zā'shŭn).

From the fertilized egg there develops an embryo (ĕm'brĭ-ō), or baby plant. This embryo has developed inside the ovule, which becomes the seed of the plant. Also, while the seeds are developing, there are certain transformations taking place in the ovary itself, and it becomes a fruit. So we find that after fertilization three things happen at the same time: the fertilized egg develops into an embryo; the ovule changes into the seed—in our pea, it becomes the pea which we commonly have on our dinner table; and the ovary becomes the fruit--in our pea flower it becomes the whole pod.

Most of us have planted seeds and watched them grow. It is remarkable how seeds that look very much alike develop into plants which have such different appearances and such marked variation in size. But always the vital thing is the same—the giving to the seed of that mysterious germ of life that will make a new plant with new flowers and fruits. If you plant a pea seed, you will always get a pea plant and not an oak or a corn plant or a bean plant. Nature never makes a mistake in these important matters.

Reading Unit No. 18

WHAT THE INSECT DOES FOR THE FLOWERS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What pollination means, 2-107-8
How insects pollinate flowers, 2-108-12
How flowers force insects to pollinate them, 2-108-12
Other means of pollinating plants, 2-112-13

Things to Think About

How big are pollen grains?
What do we mean by cross-pollination?
How are bees forced to pollinate the barberry?
How does the Dutchman's pipe make sure it is cross-pollinated?
How do flowers keep out unwelcome insects?
Why do grasses have feathery stigmas?

Picture Hunt

What is usually stuck to the hairs of a honeybee? 2-107
What happens to pollen grains on a stigma? 2-108
What does a honeybee remove from a flower? 2-109
What is said to have been responsible for the success of flowering plants? 2-111
What is the "silk" of corn? 2-111
Why do grasses produce a great deal of pollen? 2-112

Leisure-time Activities

PROJECT NO. 1: Watch insect activities in and about flowers to see how flowers make insects pollinate them, 2-107-11.

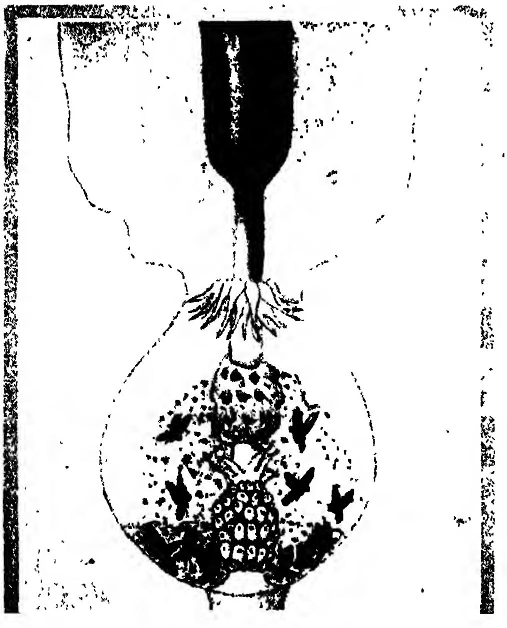
PROJECT NO. 2: Take some stamens from different flowers, crush the anthers, and examine the pollen under a microscope, 2-112.

Summary Statement

Flowers develop beautiful colors, attractive odors, nectars, and unusual shapes in order to attract insects. These insects carry pollen to other flowers of the same kind and deposit the pollen on stigmas. This results in cross-pollination, which produces stronger seeds.

1. This plant, called wild arum, or sometimes cuckoo-pint or wake robin, attracts midges by its unsavory smell, just as the Dutchman's-pipe does.

2. As in the Dutchman's-pipe, the midges pass into the lower chamber and are imprisoned by the downward-pointing spikes at the opening.



3. The midges have come in covered with pollen from an older flower, and this they have rubbed off on the stigmas at the base of the spadix, or fleshy spike. Then, and then only, the purple anthers above ripen and shed more pollen on the insects, who are still held fast in their prison.

4. By now the ovules of the wild arum have become fertilized, and its guests have become loaded with pollen from their host's anthers. The spike and spathe wither, thus releasing the insects, which are now free to carry the pollen to another plant—there to repeat the process.

Photo by Cornelia Clarke

The industrious honeybee is here pictured much more than life-size, so that we may the more easily see her with her hairy coat all plastered over with flower pollen. She goes to a flower after nectar to make into honey and pollen to feed to the young of the hive; but as she takes these for herself she also brushes against the flower stamens and comes out with her coat dusted with extra pollen. Then she visits another flower, where the pollen she carries rubs off against the sticky stigma of its pistil. The pollen she has thus unconsciously transferred grows its tube down to the ovary of the second flower and fertilizes the ovule there. And thus Mistress Bee has cross-pollinated the flower!

WHAT *the* INSECT DOES *for the* FLOWERS

You See Him Buzzing about Them, Looking for Nectar; but Do You Know Why His Visit Is All-important?

TRULY many wonderful things are happening in the plant world; and pollination (pŏl'ĭ-nā'shŭn) is one of the most amazing. How the plant will develop pollen grains in the anthers of its flowers, and then have them carried from their first home to the stigma, eventually to reach the ovules and make a seed, is a never-ending wonder! But to understand what we are going to say about it you will need to read what we have already said about the parts of a flower.

It is always interesting to look at the different kinds of pollen (pŏl'ĕn) grains that are developed in different plants. Of course, we must have either a high-powered hand lens or a microscope in order to make such a study. Let us take anthers from some of our common plants and split them so that we free the pollen grains. We find that in our beautiful forget-me-not the pollen grains are very small and remind us of mere specks of dirt. On the other hand, the delightful four-o'clock and the cucumber present us with comparatively large grains. Nearly all the pollen grains we examine will be somewhat like a football in shape, with much sculpturing. In mistletoe and water lily,

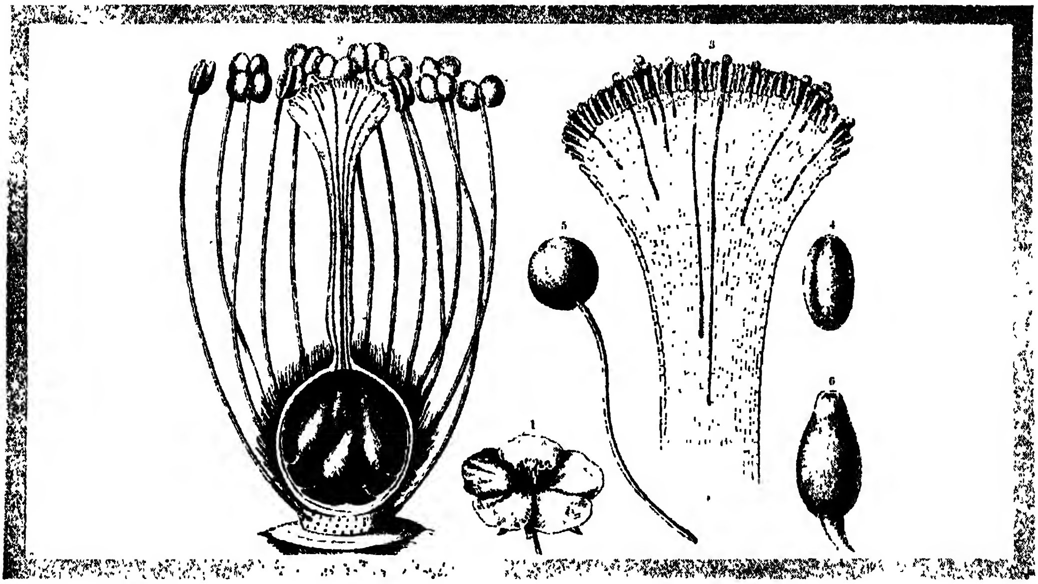


Photo by Cornelia Clarke

If you study these diagrams you will have no trouble understanding what happens when a flower is pollinated. This particular flower is a rock rose. Fig. 1 shows a single flower, natural size. In Fig. 2 it has been enlarged 22 times, the petals and sepals have been stripped off, and the pistil is shown split down the center. The pollen has fallen on the stigma, and the growing tubes show as fine lines passing down through the style and into the ovary, where each one enters an ovule to fertilize it. In Fig. 3 the stigma and the upper part of the style are shown even more enlarged, so that we may see the pollen grains attached to the stigma and beginning to grow downward. Fig. 4 shows a single dry pollen grain, enlarged 300 times, and Fig. 5 shows it moistened and developing its tube. Fig. 6 is an ovule, enlarged 50 times.

the surface of each grain is dotted with warts, while in dandelion and sunflower sharp, needlelike prickles cover the surface. These various markings make the enlarged pollen grain very beautiful to look at.

The Wanderings of a Grain of Pollen

We may wonder exactly what happens to a pollen grain when once it is freed. Now this will depend greatly upon the kind of flower it comes from. In some cases pollen from the anthers of a flower will pollinate the stigma of that same flower. The violet is a flower of this kind. Such pollination is called self-pollination. In this plant the showy flower that we see is almost always sterile (stĕr'ĭl)—that is, it rarely bears any seeds. After the showy flowers have dropped from the plant, small greenish flowers are produced which never open. These produce the seeds of the violet without cross-pollination.

But usually a flower is so developed that its pollen is rarely used to pollinate its own stigma. Cross-pollination—the carrying of pollen from the anther of one flower to the stigma of another flower of the same kind—seems to be better for most plants. To many a flower its own pollen is largely or wholly useless, since it will produce good seed only when carried to another flower of the same kind.

This carrying of pollen from one flower or plant to another is accomplished in various ways. Sometimes the stamens of a flower are shorter than the stigma, and of course no pollen will of itself travel uphill. Others mature their stigmas and pollen days or hours apart, and then, of course, they are of no use to each other. And, as we shall see presently, there are other ways to prevent self-pollination.

How Flowers Attract Insects

Insects are the chief pollen carriers, and the flowers have all sorts of ways of making the insect visitors welcome. The common barberry bush has a very strange way of greeting the useful bees who come for the nectar near the base of the flower.

Photo by Cornelia Clarke

In collecting her nectar, this honeybee has become so thickly covered with pollen that she is barely able to fly off with her double load.

Photo Cornelia Clarke

This looks like a daylight robbery—but really the bee will render a service in return for the nectar she takes. For observe that her weight has borne down the petal on which she alighted and brushed the pollen-weighted anther against her back.

The barberry has six stamens. Now these stamens have anthers which are fitted into little socketlike pouches on the petals in such a way that any bee can go directly to the center of the flower without touching one of the anthers. When the busy fellow comes buzzing in, his body is usually covered with pollen from another flower. As the bee goes down to the heart of the flower, he brushes his pollen-coated body against the sticky stigma. He cannot help doing so, for he must poke about for the delicious nectar, which is all that he wants from the barberry.

But the nectar is down at the base of the flower, and nearly hidden by the broad bases of the stamens. Impatiently the bee pries these apart, so that he may reach the hidden sweet. And that irritation of the stamens is a signal for the barberry! Immediately the two stamens that are pried apart fly out of their sockets and give the bee a rap on the back. He does not know that each of those smart taps has powdered him with pollen. So off he goes to repeat the process in another flower.

The flower gets foreign pollen and the bee gets a little nectar, but along with it he gets a rap on the back. The whole process makes it impossible for the bee to get pollen from the flower until after he is well inside and has already pollinated the stigma with foreign pollen. Then he must carry off a load of fresh pollen because he has set off the trigger that gives him a fresh coat of it.

The gas plant is a European herb often cultivated in old gardens. It gets its name from the fact that it throws off a gas which on quiet days will make a faint flash when lighted with a match. It has ten stamens, each anther of which is loaded with pollen. But the anthers, as in barberry, are tucked away out of sight; the very center of the flower is always open, except when one of the stamens guards the way.

The stigma is never ready for pollen when the stamens are full of it. When one of the ten anthers comes out of hiding, it hangs quite uselessly over the stigma, for any pollen that falls on the stigma then will do no good. But every insect that comes in is dusted with this pollen, which is of no use to the flower that gives it to him, but only to some other blossom. The insect goes off after getting his nectar, and with him he takes a load of pollen.

Ten different times this happens once for each anther—and ten different insects leave with their loads. And still the stigma is not ready. Will the flower never be pollinated? Has the need for cross-pollination been carried so far that the flower will produce no seeds at all?

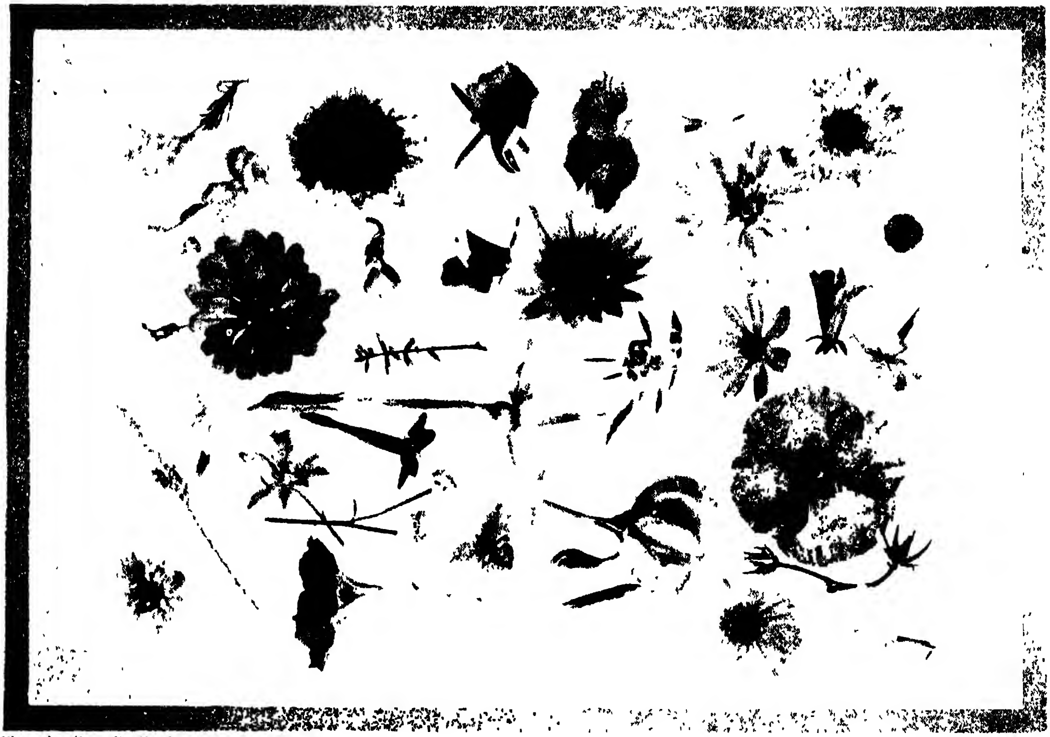


Photo by Cornelia Clarke

All the fascinating shapes and colors of flower corollas have helped attract insects which might aid in cross-pollination. Some scientists think that one reason the flowering plants have prospered until they are the most successful plants to-day is that they have succeeded so well in tempting insects to do them this service. So we probably have the insects to thank for the brilliant beauty of the flower world about us a beauty faintly suggested by the array of flower shapes in our picture.

But after the last of the ten stamens has gone back to its pouchlike socket, the stigma is finally ready; there is no longer any danger of home pollen being used! Then an insect comes along covered with pollen from another flower. This time the stamens keep out of the way, and the insect covers the stigma with the foreign pollen. That makes cross-pollination absolutely sure.

When Insect Visitors Fail

If the tardy gas plant has no final insect visitor, will it fail to get any pollen? It looks so. But no! The ten stamens then rise in a body from their pouches and scatter the remainder of their pollen on the laggard stigma. That means self-pollination unless the flower is already fertilized.

Not many cross-pollinated plants are so lucky as the gas plant when insects fail. In North America there is a vine, known as Dutchman's-pipe, which takes no chances, but has a curious way of seeing to it that its insect visitors cannot fail. It even provides a cozy two-room apartment for them

This apartment is the flower of the Dutchman's-pipe. It has a bad smell, and only certain kinds of midges are attracted by it. The flower lacks petals, and the sepals are united to form a tube. This tube is bent and constricted in the middle, so that there are really two chambers, one on either side of the constriction. The constriction is lined with bristles which always point toward the inner chamber. It is in the inner apartment that we find the pistil and stamens of the flower.

Unlike the gas plant, the Dutchman's-pipe has a stigma that matures usually several days before its own pollen is ready; so it is never self-pollinated. As we shall see presently, its insect visitors usually come dusted with pollen from outside flowers.

The insect comes in fast enough, and of

Photos by Cornelia Clarke

Insects do not do all the work of cross-pollination. Very many plants, such as the corn and timothy grass pictured above, depend for that service on the wind. Corn has two kinds of flowers. Those at the tips of the stems, shown in the larger circles, bear only stamens, from which the pollen is shaken out by the wind. Those below, in the smaller circles, bear only pistils. These, of course, are the ones that ripen into fruity ears; the stigmas, which reach far out to catch the wind-blown pollen, are the long corn silk. The timothy, on the other hand, bears both pistils and stamens on the same flower. You can see very well in this picture how immense a quantity of pollen a wind-pollinated flower has to produce, since the wind is so wasteful a carrier. But these flowers do not develop sweet scents and brilliant colors, for the wind—unlike the insects—cares nothing for such things. So they are not our most beautiful flowers.

course explores this curious two-room apartment with the curved passageway between the rooms. Once it makes its way into the inner chamber, it finds that the walls are a bit too smooth for walking and so it begins to fly about. In its flying it cannot avoid brushing against the stigma, and if it is carrying any pollen, some will be left on the stigma. After flying around for a while, the midge grows restless and tries to leave through the same passageway by which it entered. But the hairs which line this passageway block its way.

So the midge is held prisoner in the inner

chamber. Usually after two or three days the anthers open and let the mealy pollen fall to the bottom of the chamber. The pollen is food for the midge, which eats freely of it. In bustling around the bottom of the chamber, the midge manages to cover itself with much pollen. At about the time when the anthers open, the hairs which block the passageway wither and shrink. So at last the midge can make its exit with ease. Apparently it does not remember its temporary captivity, for shortly after it leaves one flower it creeps into another.

Few flowers have developed such impolite methods to make sure of cross-pollination. Most of them have simple ways. So many plants rely on insect pollination that there are hundreds of ways by which it is brought about. Of course, these plants usually develop ways to prevent the entrance of insects who would take pollen and perform no sort of service in return.

For many flowers cannot afford to be very generous with their pollen. Their pollen stores are low and are needed to pollinate a neighboring flower. Such flowers often have some kind of guard that protects the pollen from triflers. And they also protect their nectar from insects that might reach it without taking away any pollen.

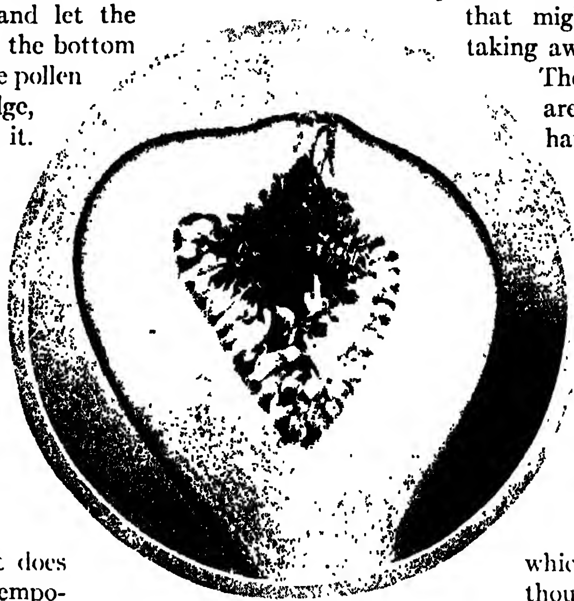


Photo by Field Museum

This is an enlarged section of a caprifig, or male fig; it is not the edible variety, but is used to insure pollination of the edible kind. The numerous flowers are *inside* the fleshy "fig," male flowers above, female flowers below. The fig wasp lays its eggs in the female flowers. When the wasps develop, the males stay in the fig and the females go out looking for more figs in which to lay their own eggs. As they go they carry pollen from the male flowers and leave it, with their eggs, in the female flowers of another fig.

The best-guarded flowers are those with fuzzy hairs on the inside of the petals, such as our common speedwell and hundreds of other blossoms. Crawling creatures like the ants, which are commonly useless to the flower, are kept out by these hairy guards. That leaves the nectar for long-tongued butterflies, which do great service to thousands of blossoms.

In the common lilac the nectar is guarded by a flower tube so narrow that only a needlelike tongue can reach it. As the tongue goes into the tube it gathers no pollen, for the tiny grains will not stick to it. But as the insect draws out its long and now nectar-coated tongue, a small load of pollen sticks to the nectar, and so is carried to the next flower.

Photo by American Museum of Natural History

These pollen grains from many flowers give some idea of the great variety in shape and size and markings that exists among the various kinds of pollen. Of course these grains are enormously enlarged.

But insects are not the only animals that carry pollen. The quick humming bird can be frequently seen hovering over a flower while it pokes its bill down the tube. Many tropical plants depend on the humming birds for their cross-pollination. In the Tropics there are certain kinds of bats that become very effective

pollen carriers. One of the most interesting of the tribe is the "flying fox," which darts about tropical forests soon after sundown. Like most bats, it lives mainly on insects which it catches in flight. But it also needs vegetable food, which it gets from the flowers of the screw pines. It is on such visits that the flying fox brings about pollination.

Insects and birds and bats are not the only pollen carriers. One little water weed, which flowers just above the water level, drops masses of sticky pollen on tiny boat-shaped sepals. No insect helps these tiny craft, which float about with their precious cargoes. Each craft is scarcely an eighth of an inch long, so that it takes a rather perilous journey. But on and on the boats may drift until by chance they sail into effective harbors. These harbors are to be found in other patches of the same kind of water weed. There the pollen grains may stick to the stigmas of the flowers. Many of these tiny craft are lost and never find a proper destination.

Plants have still another method of carrying on cross-pollination, and that is by means of the wind. And many such plants as conifers, oaks, beeches, poplars, the majority of the palms, and grasses—including most of the cereals—use only the wind for pollination.

One striking characteristic of these plants is the lack of conspicuous and fragrant flowers. The sepals and the petals of the flowers are generally small and of a yellowish or greenish color. The inside of the flower has neither nectar nor perfume. It is of no advantage to these flowers to be visited by insects.

All of the truly wind-pollinated plants produce numerous pollen grains, which are smooth, dry, and dustlike, and can be carried about easily. In some of these plants we find the anthers loosely suspended from the tips of the filament and dangling in the breezes, thus releasing their pollen. Usually there is some arrangement made by which the anther may shake and quiver.

Finally we find that the stigmas of wind-pollinated plants are different from those of the insect-pollinated ones. Invariably they are fashioned to catch the dusty pollen. In one case they are fleshy and enlarged and have the exposed surfaces covered with a velvety coating; in another they are in the form of long branching filaments. Sometimes they assume the shape of delicate feathers. In corn the silks are elongated stigmas to catch the pollen. At the time of pollination, the stigmas are always fully exposed to the wind and so placed that when pollen grains are blown against them, the grains are caught like gnats in a spider web.

So we find that the seed-bearing plants use three methods for the carrying of pollen from one flower to another. The most common is the one in which insects and other animals unknowingly act as carriers. But in some plants the flowers are so constructed that they can make use of the wind for spreading pollen from flower to flower. And, in a few instances, water is utilized in pollen transport.

Photo by Cornelia Clarke

Our honeybee is hurrying home with her load of delicate nectar, but on the way she will visit yet another blossom and will leave in it some of the precious pollen that you see scattered in fine grains on her body.

BOTANY

Reading Unit
No. 19

FROM APPLE FLOWER TO LUSCIOUS APPLE

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How flowers become fruits, 2–115-16
What a fruit is, 2–115
What the pulpy part of an apple came from, 2–116
Where apple seeds form, 2–116
Why apples are shiny, 2–116
The color of apples, 2–116

Things to Think About

What do ripe plant ovaries contain?
From what tissue is the juicy part of an apple developed?
What are the tiny threads on the side of the apple opposite the stem?
How does an apple differ from other fruits?
Why can the skin of apples be made shiny?

Picture Hunt

Why must a farmer thin out his apple crop? 2–115
Why do apple trees bear flowers? 2–115

Related Material

Why do farmers encourage beekeepers to use their orchards? 2–107-13

Leisure-time Activities

PROJECT NO. 1: Cut an apple across its equator and study the arrangement of its parts. Can you find where the ovary ends and the receptacle begins? Count the number of seed chambers.

Summary Statement

Like all fruits, apples develop from flowers. An apple differs from most fruits in having not only a ripened ovary containing seeds, but also a fleshy, juicy receptacle, which we eat. Apples have a waxy skin which is shiny and waterproof. Pigments in the skin cells give color to the apple.

Photo by Canadian National Rys

What is more beautiful than an apple orchard in full bloom? The flowers are borne in extravagant numbers so that the stems are almost hidden. If every flower produced an apple the tree could not bear the weight. This never happens; but sometimes, if the owner of the orchard does not thin out the young fruit, so many apples develop that he has to put props under the more heavily laden limbs.

From APPLE FLOWER *to* LUSCIOUS APPLE

This Will Show You What Happens from the Time When the Pink Blossoms Come in the Spring to the Time When Their Fruit Is Ready for Your Lips

THERE are many transformations which go on in plants during their lifetime, and in most cases very little is known about these changes. One of the greatest of them is the one which we find going on in the flower when the fruit is formed. For surely no one who has not seen it happen would guess that parts of the dainty apple blossom could become the apple, full of juice and pulp. But what has taken place is a good deal like what takes place in all flowering plants in the fashioning of their fruits. For no matter what their size or shape, whether they are apples, pumpkins, or peanuts, the fruits must all come from flowers—flowers whose stigmas have caught pollen grains. The various parts of a flower you will find described on other pages of this book.

But the pollination of the flower only begins the processes which turn the blossom into an apple. Many changes must take place before we can take a bite from the juicy fruit.

Most fruits are made up of the ripened ovary of the flower, with seeds inside it. A common grape, for instance, consists only of the transformed ovary—in this case very much swollen and full of juice—with the ovules embedded in the flesh in the form of "pits," or seeds.

But apples differ from most fruits in that the part one eats is really not part of the ovary at all. When you throw away the

"core" of the apple, you have thrown away the ripened ovary of the apple blossom. Where, then, does the juicy flesh come from?

The flower of an apple has five petals and five sepals, but if you look carefully you will see that while the petals are separate and free, the sepals are not. Only their five lobes, at the top, are separate. At the base the sepals are united to form a cup, or bell-shaped calyx, which gradually tapers into the swollen stalk of the flower. That swollen base of the apple blossom is going to play an important part in the fruit development. It is called a "receptacle," and is found in many of the flowers of the apple family.

Inside the row of petals there are several rows of stamens, and inside them, at the very center of the flower, is the pistil with its ovary. Perhaps at first you see only the five scarcely separated "styles" of the pistil. They are nearly free toward their tips, but are united over the base, where they join the ovary.

If you cut an apple flower across its ovary, you will see that it has five compartments, each usually with two tiny ovules inside it. Each of these compartments opens into a style, which, as in most flowers, ends in a stigma. But if you cut an apple blossom lengthwise you can see for the first time that the ovary is more than half embedded in the swollen "receptacle," and that its ovules are well below the upper edge of the receptacle.

As you now understand the apple blossom, it has a rather sunken ovary in a half-inclosing receptacle. This receptacle really has a very complex structure. The lower portion of it is the uppermost part of the stem, which has become much broadened. The upper portion of it is composed of the lower portions of the sepals, petals, and stamens, which have fused together into a fleshy mass.

After pollination has taken place, the upper parts of the petals and stamens wither, leaving the ovary surrounded by the "receptacle."

Once fertilization has taken place, the ovary and its ovules begin the slow process of changing into fruit and seeds. In most flowers the whole fruit is formed when this work is finished. But in the apple that process produces only the "core" of what we call the fruit.

The best way to see this is to cut an apple across. Then we can easily find the original five compartments of the ovary. They have a parchmentlike shell, which is the old ovary wall much enlarged. And instead of the ovules, we find shiny brownish or blackish seeds in each cavity.

This is all that the ovary of the apple flower ever develops into; and it is the part of the apple which we discard when we eat the fruit. Yet it protects the seeds very nicely.

While the ovules are ripening in the ovary, the receptacle grows up around it. So before the fruit is even partly mature, the ovary is almost completely inclosed in the developing receptacle. This is a remarkable process for, while fertilization is accompanied by great changes in every ovary, it is accompanied in the apple by a growth of the receptacle as well.

As the receptacle grows about the ovary, it seems to draw together at the top the free parts of the sepals and stamens, which never drop as the petals do. One can still see the remains of these on any fresh-picked apple. In many apples that one buys at the store, the calyx lobes have been rubbed off, but their scars can be seen plainly enough.

In developing, the receptacle changes from a little, hard, green, cup-shaped structure to a larger, fleshy, edible one. Usually it is a gradual change, and the time required for it will vary with different kinds of apples.

Along with the development of the "flesh," we find the "skin," or epidermis (ĕp'ĭ-dûr'-mĭs), forming. On the surface of the "skin" waxy, water-proof substances are produced which give the shiny appearance to most apples. If it were not for these waxy materials, the apples would not shine when rubbed. When most apples reach maturity, certain pigments—or coloring matter—usually red, develop in the cells of the skin. These pigments add to the attractiveness of the apple.

Many other fruits besides the apple develop only as great changes take place in the parts of the original flowers.

BOTANY

Reading Unit No. 20

WHAT A FRUIT IS FOR

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What a fruit really is, 2–119
The amazing variety of fruits, 2–119-22
What fruits do for the plants that produce them, 2–119-20
How seeds are spread far and wide, 2–119-20, 121, 122
The different sizes of fruits, 2–120
Accessory fruits, 2–122

Things to Think About

Why may string beans be called fruit?
How do birds help in carrying seeds to all parts of the country?
How many kinds of fruit can you name?
Why are not corn kernels considered seeds?
How do pods scatter their seeds?
Why is the apple called an "accessory" fruit?

Picture Hunt

Can you recognize this fruit from its picture? 2–110
How are dandelion seeds scattered? 2–120
When you eat corn on the cob how many fruits are you eating? 2–118
Name the true berry in this picture, 2–118
Is the tomato a fruit? 2–121
What part of the peach do you eat? 2–121
Why is the cucumber called a fruit? 2–121

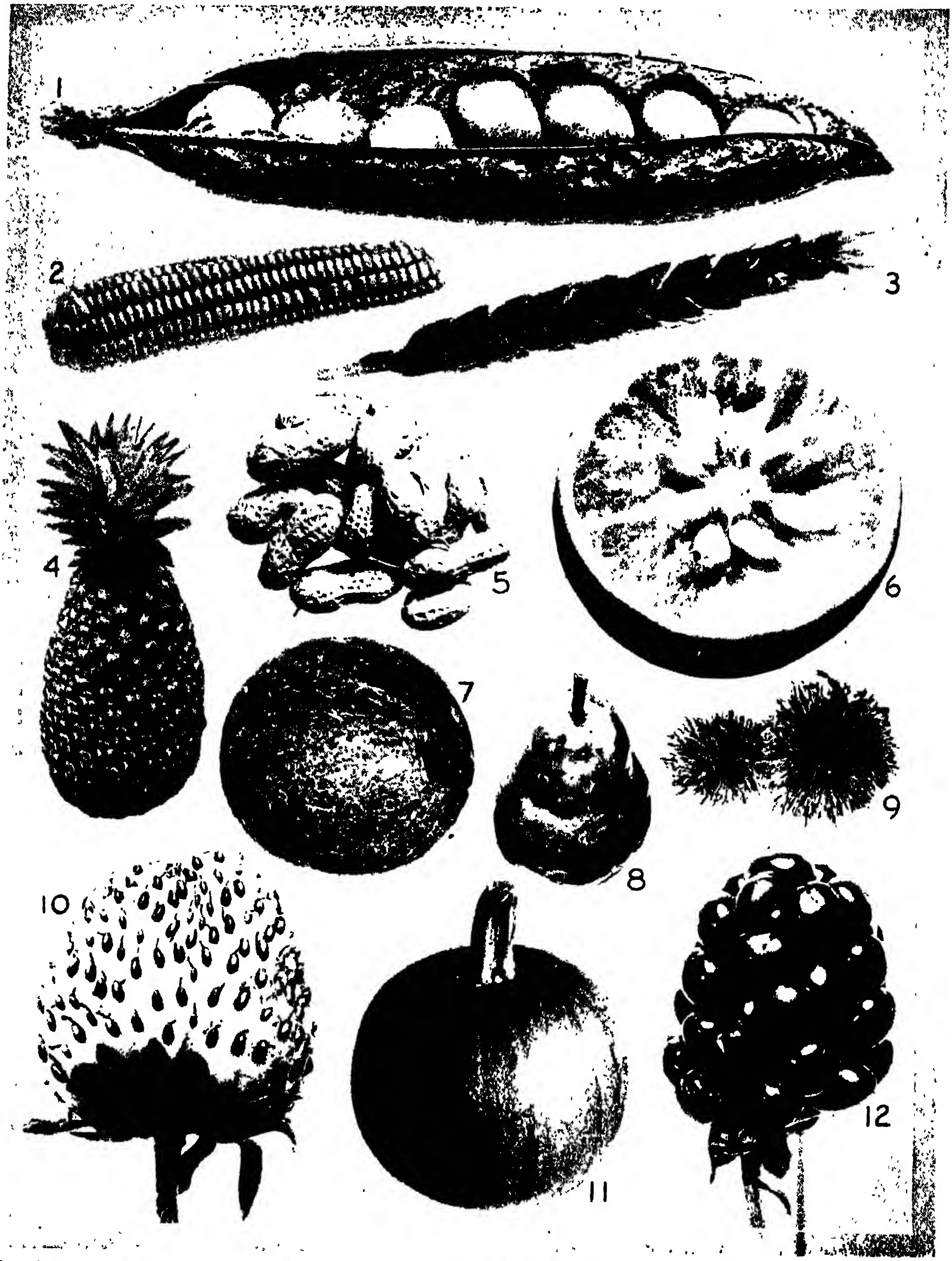
Leisure-time Activities

PROJECT NO. 1: Make a labeled collection of different kinds of small fruits. Keep them in test tubes, putting alcohol on the fleshy fruits to preserve them.

Summary Statement

Fruits are ripened ovaries, which sometimes have other parts attached. Fruits contain seeds. Some fruits are dry, others fleshy. Some fruits have parachutes which carry them along. Fruits are spread over the country by birds, man, and other animals, as well as by the wind.

WHAT A FRUIT IS FOR



Here is a page of common fruits, showing some of the ingenious ways in which the plants wrap up their seeds. 1. A pod of peas—the peas are the seed. 2. An ear of corn—each kernel is a complete fruit. 3. A spike of wheat—each segment is a fruit, with its seed attached tightly to the seed coat. 4. Pineapple, a multiple fruit. 5. Peanuts, fruits with dry shells. 6. Orange, a hesperidium. 7. Coconut seed—this is what we usually call a coconut, but really the walls of the fruit have been removed. 8. Pear, a variety of pome. 9. Chestnut burrs—the nuts are inside. 10. Strawberry--not really a berry but an accessory fruit. 11. Pumpkin, a kind of berry called a pepo. 12. Blackberry—not a true berry but an aggregate fruit.

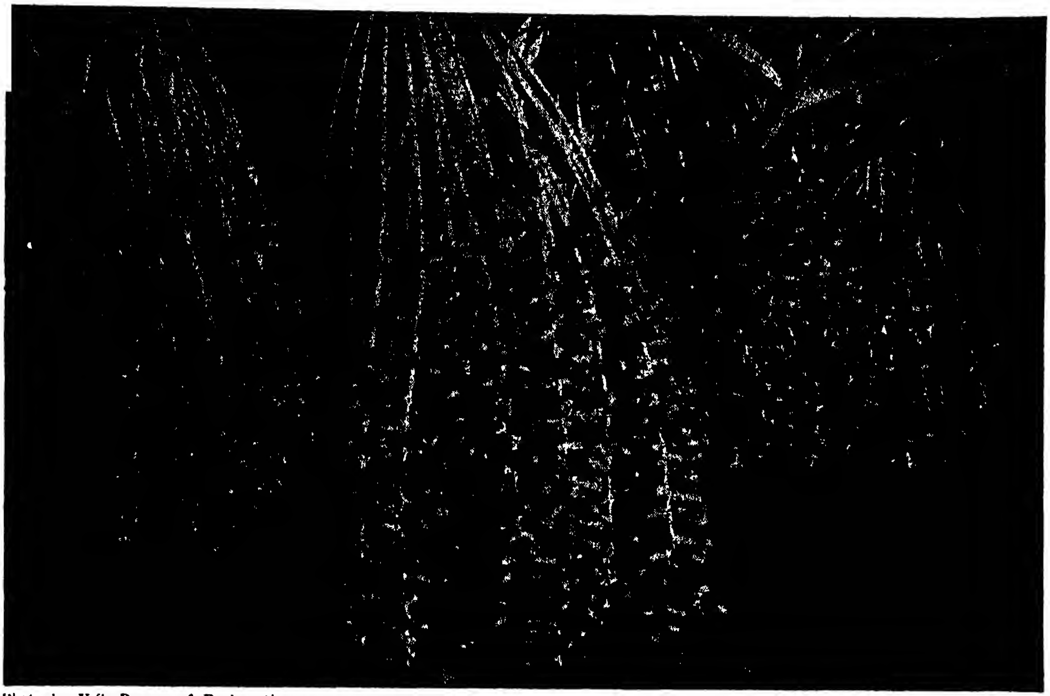


Photo by U S. Bureau of Reclamation

You may have to guess a good many times before you can name this fruit. Though you may have eaten it in large quantities you have probably seen it only when it was wrinkled and brown and very sticky. For the dates you ate were dried. Because they are rich in sugar and protein dates are a daily food in parts of Africa and Asia. The roasted seeds can substitute for coffee, and when ground yield oil and food for stock.

WHAT *a* FRUIT IS FOR

Not at All for Your Delight, However Sweet It May Taste; in Nature It Has a Far More Important Purpose

IF YOU ask the average man what a fruit is, he will generally say that it is something that grows on a bush or tree and is good to eat. This would not give us any idea as to what a fruit really is. There are only a comparatively small number of fruits which are good to eat, while there are many thousands that no one would ever taste. Some of them are highly poisonous.

A fruit is always formed from a part or parts of a single flower or a group of flowers. It may be an acorn or a watermelon, a grain of wheat or an orange, a string bean, grapefruit, tomato, or peanut. Fruits may take the most varied forms. They may be spiny, as in some of the cacti, soft and luscious like the pear, rich and oily like a peanut They may be the things we commonly call vegetables, such as string beans, pumpkins, and squash. Or they may be such things as we always think of first when we speak of fruit—the delightful strawberries, melons, apples, plums, peaches, and oranges that we know so well. Most of these latter things are no longer wild fruits, for man has done much to domesticate and develop them.

The fruit plays an important part in the lives of most flowering plants. In the first place, it provides a protected place where seeds may mature. Sometimes this protection is rather meager, while at other times it may be more than sufficient. Secondly, many fruits help in the distribution of the seeds. Sometimes the fruit is so fleshy that the birds like to eat it, and then they carry the seeds all around the country—perhaps to

places many miles away. Sometimes the fruit is sticky, like the tick trefoil, so that it clings to your clothing or to the fur of animals, and gets the seed or seeds carried to new regions in that way. Some of the fruits, such as the witch-hazel and jewelweed or balsam, shoot their seeds as far as ten or fifteen feet. Still others, such as the fruit of the dandelion, have tufts of hairs so light that the wind may carry them considerable distances.

Photo by Cornelia Clarke

Here is a flower stalk of the dandelion when all the fruits are ripe. Each fruit has a crown of fine hairs so light that the fruit can float far and wide through the air, borne by the wind. Thirty or forty thousand of these feathery fruits weigh only one ounce.

We know about 150,000 different kinds of flowering plants, and most of them bear fruits. The simple fruits may be arranged in two main divisions, those that are fleshy and those that are dry. All of these, except a few like the mulberry and fig, develop from a single flower. From a single watermelon flower there may form a fruit weighing fifty to a hundred pounds or more, while from a dandelion flower there may develop fruits so light that it would take from thirty to forty thousand to weigh an ounce. The two main divisions of fruit may again be divided into a number of subdivisions, all containing fruits of many kinds.

Of the many different simple fleshy fruits, there are only two main types. On the one hand there are the true "berries"; on the other there are the fruits that carry their seeds in stones, such as plums and cherries. These last are called "stone fruits," or "drupes," from the Latin word "drupa," which means "an overripe olive."

It is rather difficult to tell what a true berry is. Generally we say that a berry is a fruit that develops with a fleshy, pulpy wall inside of which there are buried one or more seeds. Grapes and currants are true berries, and so are peppers and tomatoes. And so, of course, are cranberries and blueberries. This does not mean, however, that all fruits called berries are true berries. Mulberries, raspberries, blackberries, strawberries, and many such fruits are not true berries according to the definition.

In contrast to the feathery dandelion fruit, which seems almost weightless, consider this enormous watermelon, which weighs many pounds. It is one of the heaviest of the type of fruit called a pepo.

Photo by Cornelia Clarke

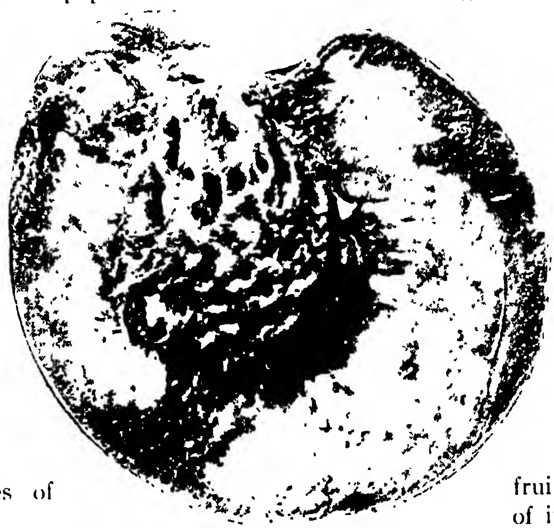
Many berries are either sweet to the taste or brightly colored, and so they are attractive to birds. Most of them have hard seeds rather than soft ones. This is fortunate, for otherwise the seeds of many would be destroyed during digestion in the bird's stomach. As it is, berry seeds that have been eaten and dropped by birds and other animals are scattered far and wide.

Photo by Cornelia Clarke

The round, red fruit above is, of course, a tomato no one needs to be told that. But could you have told before you read this story that a tomato is a berry?

There are some fruits which are really berries, even though they are called by different names. Some, though fleshy inside, have hard rinds; such are the cucumber, watermelon, and pumpkin. Such a fruit is called a "pepo" (pē'pō), a Latin word for a kind of melon. Still others have a leathery rind such as oranges, lemons, grapefruit, and other citrus fruits. The name for such a fruit is "hesperidium" (hĕs'pĕr-ĭd'ĭ-ŭm), a word that recalls the ancient Greek myth of the "golden apples" in the garden of the Hesperides. You will find the tale on other pages of these books.

The stone fruits, or "drupes," are well known to all of us. Besides the peaches and the plums, the cherries, prunes, and olives, there are hundreds of other trees, mostly wild, bearing a fleshy fruit with a single hard stone which we have to crack open to find the seed inside it. In all these, as they change from flower to fruit, thin-walled cells on the inner side of the fleshy ovary wall become hard, thick-walled cells. Like most cells, these are so small that we cannot see them without a microscope. But in the end we can see that these cells finally form a hard, stony coat around the seed. And during all this the outer wall of the fleshy ovary has gone on swelling to form the flesh of the fruit—the part of it that we are so glad to eat in the cherry or the peach.



Photos by Cornelia Clarke and U S Dept of Agriculture

Above is a stone fruit, a peach, cut so as to show its stone. The hard wall of the stone and the soft flesh are both formed from the ovary wall, and are therefore both part of the fruit. The seed is inside the stone. As for the long, shiny fruit below, it is a cucumber—which, like the tomato, unexpectedly turns out to be a berry!

The pome (pōm) fruits get their name from the French word for "apple." In the apple and pear and other pome fruits, the change from the flower into the fruit is all done within a relatively short time. But many changes take place to transform the pinkish-white blossom into a ripe fruit. That we shall hear of in another story.

Most of the fruits are not fleshy but dry, and these are of far more value to us than the fleshy ones. We could get along without oranges and apples, if

we had to do so. But most of the world would starve without wheat, corn, rice, beans, and other dry fruits.

Some of us always think of wheat, corn, and rice as seeds rather than fruits. But they are all dry fruits. Dry fruits can be divided into two natural groups—those that split open, like peas and beans and hundreds of others, and those that never do, like the cereals we have mentioned, and buckwheat, and nearly all the nuts.

Fruits That Split Open

Dry fruits that split are so common that one may easily think of many others besides peas and beans. Some of these split along only one side or seam, as do the milkweed and columbine, the peony and the larkspur. But many others split along two sides or seams, like the violet, the iris, and the lily. When they are ripe, these just seem to yawn open to let the seeds fall. "Yawning" is a good word to describe what happens in many of these slowly opening seed pods, and from the Latin word for yawn, "dehiscere," we get the name for them. We call them all "dehiscent" (dē-hĭs'ĕnt) fruits. In some fruits, this splitting aids in throwing out the seeds.

Many of the important fruits in the world do not usually open, or "dehisce" (dē-hĭs'). They have no seams or lines of weakness in the fruit coat to allow for easy splitting. The fruits that do not dehisce have tight-fitting coats that completely close over the seed.

One of the common kinds of the non-splitting, or "indehiscent" (ĭn'dē-hĭs'ĕnt), type of fruit we find in wheat, rye, corn, oats, and all the other grasses. The tight coat of the fruit has fused with the seed coat, and the two cannot be separated. All of the grasses in the world have fruits of this sort.

Many other small dry fruits, though indehiscent like the cereals, do not have the fruit coat fused to the seed coat. Some of these, like the common buttercup and buckwheat, have coats which are rather leathery but not very hard. These are called "achenes" (ȧ-kēn'), from a Greek word meaning "not to yawn." If the coats are hard and stony, we call the fruit a nut, and this kind of fruit is commonly formed by many of our trees.

All of the kinds of fruit that we have mentioned so far have been those which are formed from single ovaries from single flowers. These are called simple fruits. But we have some fruits which are more complex. In one group we find fruits which are formed from a single flower, but with more than the ovary entering into the making of the fruit. These are called "accessory" (ăk-sĕs'ō-rĭ) fruits. In another group we have fruits which consist of whole groups of flowers. And these are called "multiple" fruits.

What an Accessory Fruit Is Made Of

The "accessory" fruits are always interesting, for it may be almost any combination of parts which make up the fruit. Although fruits like the apple and pear may seem to be simple, they are not. For the receptacle and stamens and petals and sepals go into the compostion of the fruit as well as the ovary. This kind of "accessory" fruit we call a pome. In the wintergreen the sepals as well as the ovary become part of the fleshy fruit. Many of the fruits commonly called berries, such as the strawberry and the blackberry, are accessory fruits. In this kind the receptacle becomes very much swollen and softened to form the luscious flesh of the fruit.

Some fruits, such as the pineapple, the mulberry, and the fig, involve more than one flower and hence are called "multiple." The flowers which make up the fruit may become tightly fused together, as in the pineapple, or they may remain quite separate, as in the mulberry. This kind of fruit is the least common type of all.

Reading Unit No. 21

THE NEW LIFE WRAPPED IN A SEED

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How a seed develops, 2–125-26
Kinds of seeds, 2–126-29
What the seed embryo does, 2–126-28
How the embryo is fed, 2–128
How seeds are protected, 2–129
How seeds help mankind, 2–129

Things to Think About

What steps lead to the formation of a seed?
What part of a seed grows into a new plant?
What work is done by each part of a seed?
How does the embryo get food?
Into what three great groups have flowering plants been divided on the basis of seed structure?
How can seeds provide food for mankind?

Picture Hunt

Why is corn valuable as a food? 2–126
How are chestnut seeds protected from hungry animals? 2–127
From what do we make cocoa and chocolate? 2–127
How are dandelion seeds spread? 2–127
What part of a pea embryo grows out of the seed first? 2–128
Name five uses of seeds in the home, 2–124

Related Material

How is flour made? 9–234
How do we get white flour? 9–236
How much flour do you eat every year? 9–236
How many kinds of flour do we use? 9–233

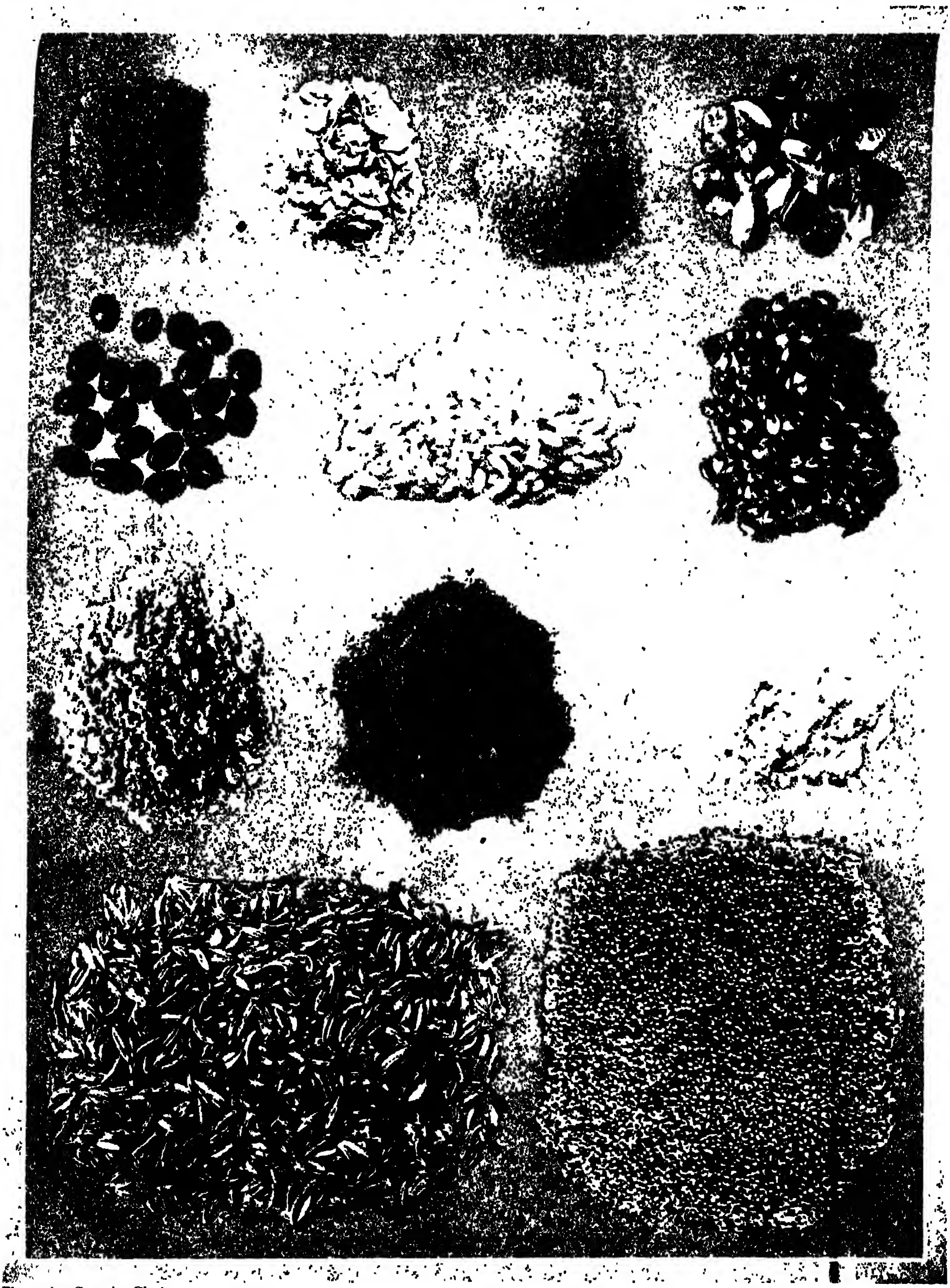
Leisure-time Activities

PROJECT NO. 1: To find out if starch is present in a seed, add a drop of iodine to a crushed seed. Put iodine on seed products such as flour. If starch is present, a blue-black color appears.

Summary Statement

Seeds contain starch, proteins, minerals, and fats—all important nutrients. Plants protect their seeds in ovaries until the time comes to spread them over the soil at a distance from the mother plant. Wind, water, and animals distribute these seeds. In the proper soil and under suitable conditions, seeds germinate and produce new plants.

THE NEW LIFE WRAPPED IN A SEED



Photos by Cornelia Clarke

Here are only a few of our useful seeds, or products that come from them. A visit to the cupboard will add a good many more to the list. Beginning in the upper left-hand corner and reading from left to right you will find them to be, first, the spicy nutmeg, here ground for use; rolled oats; pepper, here shown ground, instead of in its little round seeds; corn; coffee; rice; buckwheat; ground mustard; cocoa, of course ground; white flour; caraway seeds, of cooky fame; and poppy seed, of great use in medicine.

Photo by Cornelia Clarke

Here are seeds of many kinds—large and small, round and oval and of many other shapes. Each one of them has a hard outer coat to protect the embryo, or undeveloped plant inside, and each holds food for the embryo to consume when it begins to grow. This stored food lasts until the little plant has green leaves with chlorophyll to make its own food. But if men like the food stored for the embryo, they eat it themselves.

The NEW LIFE WRAPPED *in a* SEED

Nature Has Made Many Thousands of Different Kinds of Seeds to Keep Life Going on Our Earth. Here We Tell You What a Seed Really Is

WHATEVER else it may do, every kind of plant must have some way of reproducing itself. This it must do if its kind is to persist. We have already mentioned that in different groups of plants reproduction may be carried on in different ways. It is in that group which generally reproduces by seeds that we are now interested.

Seeds show an odd variety of sizes and shapes. They may be brown structures with tough coats, such as are found in the core of the apple. They may be slippery, like the seeds of the squash or pumpkin or watermelon, which may be variously colored. Or they may be as different from that as is the coconut with its hard, outer layer and its milky water.

Just what are these structures that we call seeds, and how have they developed? All of our seed-bearing plants, including the angiosperms (ăn′jĭ-ô-spûrm) which bear flowers and the gymnosperms (jĭm′nô-spûrm) which bear cones, have ovules (ō′vūl) which contain egg cells. It is after fertilization has occured—that is, after a sperm cell has entered the ovule—that these ovules, increasing in size and changing in structure, become seeds. To follow such changes is very dificult, and requires much microscopic

study, but the botanists have found out a great deal about them. They have found that two general changes usually take place. The fertilized egg develops into an embryo (ĕm′brĭ-ō), and then its growth is checked. Along with this change comes the formation of a store-house tissue which is called the endosperm (ĕn′dô-spûrm). More will be told about this later.

We find seeds of many shapes. Those of the vetches and the clovers are more or less globular, as are those of the radish and others from our vegetable plants. The seed of moonwort is thin and flat. Most of the nuts, including walnut and hickory, have seeds which are very much wrinkled and irregular. Other seeds may be greatly elongated or coiled or irregularly distorted in any number of ways.

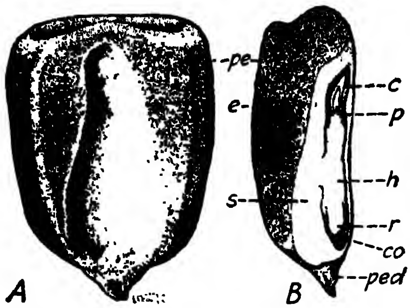


Photo by McGraw-Hill

This grain of corn is really a fruit · a fruit containing a single seed. For the outer hull is made up of the pericarp (pĕr′ĭ-kärp) —or ovary wall—and the seed coat; the two are completely fused. The sketch at the left shows the grain on the side against which the embryo lies. If the seed were cut lengthwise through the center of its broad side, the cut surface would look much like the sketch at the right. At *e* is the endosperm; *h* is the hypocotyl; *pe*, the pericarp; *ped*, the peduncle (pê-dŭng′k'l), or fruit stem; and *s* is the scutellum (skû-tĕl′ŭm), or cotyledon. At *c* is the coleoptile (kŏl′-ê-ŏp′tĭl), a sheath covering the plumule, shown at *p*. At *co* is the coleorhiza (kŏl′-ê-ô-rī′zȧ), a sheath covering the radicle, shown at *r*.

Not all seeds are smooth like those of tobacco and pear and apple. Sometimes they are wrinkled and rough-skinned, as in fennel. Chickweed has a warty coat. When the seed of the field poppy is magnified, it looks much like a honeycomb. These are only a few of the variations we find in the neat coats of seeds.

No matter what size or shape or weight seeds may have, we find that their general structure is about the same, at least at the beginning of their development. We find in all seeds an embryo which may be of various sizes and various stages of maturity. In some seeds, as in the orchid, the cells of the embryo are not clearly marked off at the time of shedding. If you tried to find the embryo, even with the aid of the microscope, you would have great difficulty. Of course, in the pear seed and the pumpkin seed, you can pick the seed apart and easily make out the embryo.

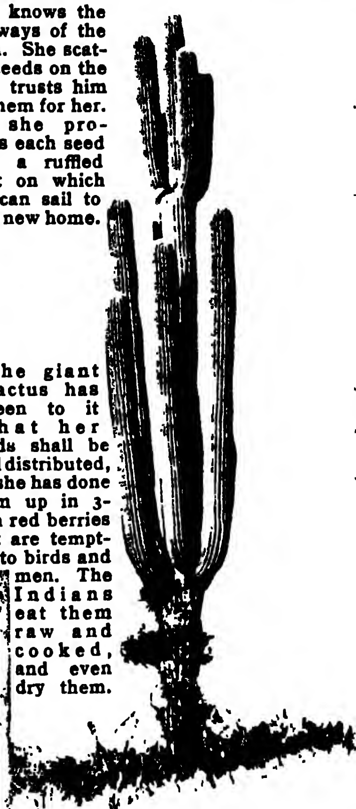
The embryo is sometimes called the "germ" of the seed. It is really the part that actually grows into the new plant. The upper part of the slender axis of the embryo is called the hypocotyl (hī′pô-kŏt′ĭl), and represents the stem. At the upper end of the hypocotyl we find very small leaves surrounding a growing point. These taken together are called the plumule (plōō′mūl). The lower part of the embryo is called the radicle (răd′ĭ-k'l), and when the new plant begins to grow, we find it forming the very important primary root. At-

Artists and designers are always going to Nature to borrow her ideas for making beautiful things. These pretty seeds, for instance, would make a charming ornament for a woman's hat—or a rattle for a baby. They were first worn by the screw pine, which is not a pine at all but a useful tropical tree belonging to the same family as the lilies and grasses. It grows with its stem perched up well above the soil on a strong prop of roots; and it gives the tough fibers in its leaves to be woven into stout cloth for making sugar bags, etc. In every one of those knobs, or "carpels," is a future screw pine.

Photo by Field Museum

THE NEW LIFE WRAPPED IN A SEED

Everyone knows the careless ways of the dandelion. She scatters her seeds on the wind and trusts him to carry them for her. But she provides each seed with a ruffled skirt on which it can sail to its new home.



The giant cactus has seen to it that her seeds shall be well distributed, for she has done them up in 3-inch red berries that are tempting to birds and men. The Indians eat them raw and cooked, and even dry them.

The chestnut is a most careful mother. And lucky it is that she is so, for her seeds are so toothsome that the little trees wrapped up inside them would seldom get a chance to sprout if their mother had not done them up in prickly coats that no animal enjoys tampering with. Of course the coat must come off before the youngster starts to grow. So the frost obligingly unbuttons it—as you may see at the right.

Of course you know that cocoa does not come from the coconut. It comes from the "cacao bean," which grows in huge pods on the cacao tree. Below is a picture of one of those pods, with its family of oily beans, which give us both cocoa and chocolate.

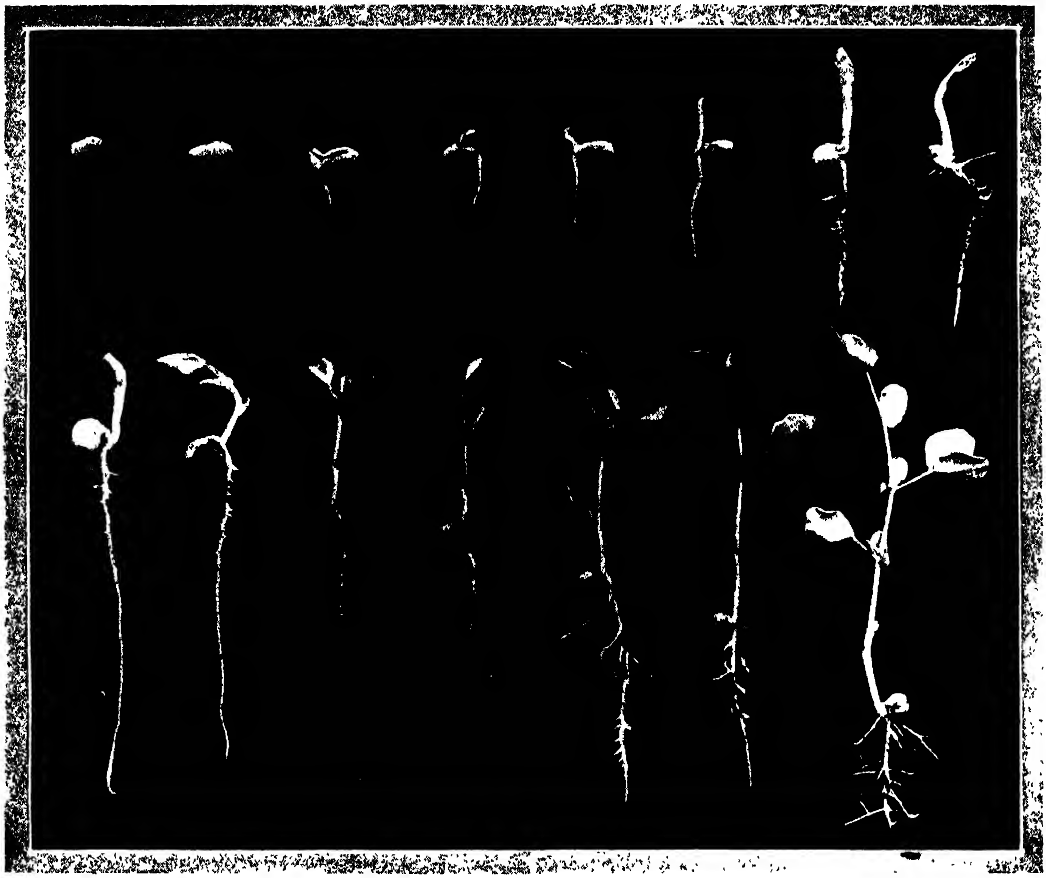


Photo by N. Y. Botanical Garden

A common garden pea sprouts in this way. If you will plant a dozen peas in a flowerpot or wooden box you can watch it all going on under your very eyes, and trace every step in the growth of the plant.

tached to the hypocotyl are one or more leaflike outgrowths. They are very conspicuous in the squash or pumpkin. Commonly you would mistake them for true leaves. They are called cotyledons (kŏt′ĭ-lē′dŭn), and act as storehouses of food for the embryos of such seeds as the bean and pea. In oats and barley, however, and in the rest of the cereals, the cotyledon acts as an absorbing structure, supplying food for the growth of the embryo.

What the Endosperm Is Like

Surrounding the embryo in the early stages of development is a storage tissue, the endosperm (ĕn′dō-spûrm). In the seeds of corn and oats and barley, we find large endosperms with great quantities of stored starch. That is the reason why we value cereals so highly. Generally, when the endosperm is so large, the embryo is small. An ordinary bean seed shows just the opposite condition. It has an endosperm in its early stages, but as the seed grows older, the endosperm is entirely absorbed by the embryo. All of us are familiar with the condition in the bean, where the embryo is next to the skin. The peanut and the pea, in fact all the members of the pea family, have the same type of seed as the bean. The squash seed shows an intermediate condition between the bean and the cereals. If you have ever opened up a squash seed, you have found just outside the embryo a very thin, greenish layer. The layer represents the remains of the endosperm after most of it has been absorbed and stored in the embryo.

The embryo and the endosperm, when it is present, are protected by an outside covering called the seed coat. Not only does the seed coat protect the seed from bruises and similar injuries, but it also prevents it from drying out too rapidly. In some seeds it tends to be a little soft, but in most seeds it is hard or tough. In the peanut it is the reddish layer which we remove before eating. The seed coats of our melon seeds are rather leathery and, when wet, grow slippery. The apple seed has a brown coat so tough that it is sometimes difficult to break.

While we cannot examine all the different kinds of seeds, there are three general kinds that we should know about. Every seed-bearing plant produces a seed belonging to one of these groups. The first kind carries only a single seed leaf or cotyledon. No plant of this kind ever shows this seed leaf, even when germinating (jĕr′mĭ-nā′tĭng)—or beginning to grow into a plant; the seed leaf remains hidden as an absorbing organ. Lilies and corn, palms and sugar cane and all the grasses, have this sort of seed. And the true leaves of these plants usually have their main veins running parallel, or side by side

The second kind has always two seed leaves in the seed. Most plants of this kind, such as the bean, will have the main veins running at angles to one another. Most of the common plants we see, such as the oaks and elms and daisies, bear seeds of this sort.

The third kind of seed is found for the most part in the pines, hemlocks, spruces, and other cone-bearing trees. They always have three or more seed leaves in their seeds.

These three kinds of plants have long names among the botanists. The first kind is called a "monocotyledon" (mŏn′ō-kŏt′ĭ-lē′dŭn), the second a "dicotyledon" (dī-kŏt′ĭ-lē′dŭn), and the third a "polycotyledon" (pŏl′ĭ-kŏt′ĭ-lē′dŭn). If you remember that in Greek "mono" stands for "one," "di" for "two," and "poly" for "many," you will see at once that the long names stand for plants that have one, two, or many baby leaves in their seeds. One of the first things a botanist wants to know about a seed-bearing plant is which of these three great classes it represents.

No other part of a plant is richer in food than the seed. It is generally in the seed that the richer food products are stored by a plant, to be used by the embryo as it begins its growth. We can see how much food is stored up in seeds if we will only think how much of it we eat ourselves. All our corn and flour, our oatmeal, rice, and buckwheat, are simply food stored for seeds. We can live on these things even though they are formed by plant tissues.

Nearly all of the kinds of food which your body needs can be found in seeds. The seeds of the cereals and grasses are packed with starches. Proteins (prō′tē-ĭn)—organic compounds which contain the elements oxygen, hydrogen, carbon, nitrogen, and generally sulphur—are abundant in many seeds. The members of the pea family, such as the locust, bean, vetch, and peanut, store more proteins in the seeds than do most plants. We find the fats more abundant in the embryo than in the endosperm. The seeds of flax, the castor-oil plant, cotton, coconut, and hemp are especially high in fats.

Seeds have always been useful to man and doubtless always will be. He eats vast quantities of them, though he makes up for this by planting and tending enough of the remainder to insure quantities which would not be produced naturally. Not only does he eat countless millions of seeds—mainly of the cereals, such as wheat and rice—but he gets all sorts of useful things from them. A list of these would fill a large book. His spices and seasonings come from such seeds as those of nutmeg, coriander, mustard, and caper. The nuts he eats are all seeds, and the coffee and cocoa he drinks are made from seeds. So are many of his medicines, like castor oil and strychnine. From the dried endosperm of the coconut, which is called "copra" (kŏp′rȧ), an oil is pressed which is used in the manufacture of substitutes for butter and lard. The vegetable ivory of commerce, from which great numbers of buttons are made, is secured from the seed of a South American palm. And you will think of many other uses to which seeds are put.

Reading Unit No. 22

BUDS AND THEIR USES

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What buds are, 2–131-34
How buds are placed on a twig, 2–131-32
Kinds of buds, 2–132-33
How buds are protected, 2–133-34
Unusual buds, 2–134

Things to Think About

Why do plants have buds?
What happens if a terminal bud is destroyed?
How does bud arrangement help us in identifying trees?
How can you tell which buds will produce leaves and which will produce flowers?
Why does the bark sometimes bear leaves and stems?
How are the insides of buds protected against injury?
What buds do we eat regularly?

Picture Hunt

What is the sex of a willow tree that bears "pussies"? 2–131
How does a bud get food and water? 2–132
How are pollards produced? 2–133
What comes out of a bud? 2–133
What kinds of buds are cabbages and Brussels sprouts? 2–134

Leisure-time Activities

PROJECT NO. 1: To make a bud collection, collect twigs showing different kinds of buds and bud arrangement, 2–131-33.

PROJECT NO. 2: Cut across several kinds of buds to see how the young shoots and flowers are arranged in them, 2–132-33.

Summary Statement

Buds are young shoots protected by scales or hairs from drying out before they grow. Although leaves fall off, the next year's crop is provided for by the buds. Buds may be opposite or alternate; single or clustered; sessile or stalked; smooth or hairy or resinous; terminal or axillary. Such characteristics make it possible to recognize trees and shrubs, even though no leaves are present.

Photo by Cornelia Clarke

The soft, velvety "pussies" which are such a welcome sign of spring are the partly open buds of certain willows. The "fur" is really fine hairs which surround the stamens of the male flower which the bud contains. When the bud opens fully, the stamens push their anthers up so that they may be seen. The female flowers of the willows are to be found in other buds that come later; the leaves come last of all.

BUDS *and* THEIR USES

Have You Ever Taken One Apart to See What Is Tucked Away Inside?

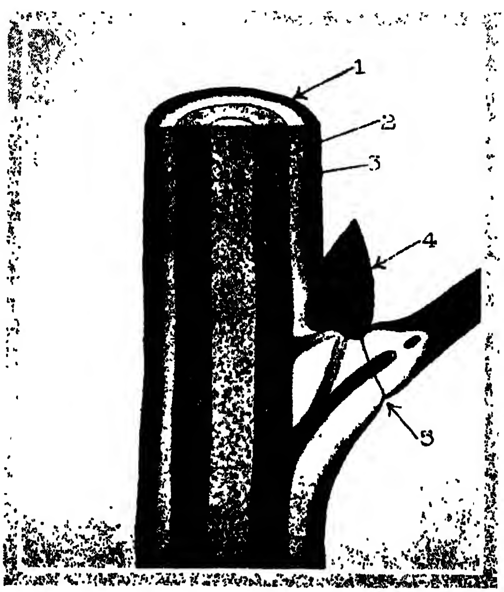
IF YOU picked up a branch of some woody plant, such as the lilac, during the winter months, you would notice scars at the places along the stem where leaves were once attached. And if you examined still further, you would find above each one of these scars a snug, compact structure which we call a bud. Not only would you find them upon all of the woody stems, but also upon the stems of many of the herbs. Each bud possesses a very small stem with a growing point and leaves; it really is the very beginning of a shoot. As we look at it externally, little do we realize its future possibilities.

It is in our woody trees and shrubs that we find our most conspicuous and best-developed buds. And in them we find great differences in size and form. Some, like those of the beech, are rather long and slender, while others, like those of the ash, are short and stout. Some are sharp-pointed, others are blunt. Some are rounded while others are angular.

The "insertion," or place of attachment of the buds on the stem, has always been interesting. Many stems, such as ash and poplar and oak, have buds that grow directly upon the twig, without a stalk. In that condition the buds are said to be "sessile" (sĕs'ĭl). If we examine the buds of striped maple, we find that each bud is

borne upon a stalk which separates it from the stem. We find another condition in the locust, where the bud is sunken in the stem with only a small part showing above the surface. Such buds are called "imbedded." Sometimes the bud may be entirely hidden by the base of the stalk of the leaf, and the leaf must drop before the bud is revealed. The common sycamore, or plane tree, shows such protected buds. The "sessile" type of bud is the most common.

Buds usually make their appearance at definite points on the stem. Where the leaf joins the stem there is an angle, and that angle is known generally as the axil (ăk'-sĭl). The buds produced along the stem are found in these axils, and hence are called axillary (ăk'sĭ-lâ-rĭ) buds. These axillary buds may occur singly or in groups; either one above the other, or side by side. Perhaps in most trees the axillary buds remain single. The butternut has axillary buds in a group, one above the other. In the red maple, on the other hand, the axillary buds occur side by side, the middle one usually the most vigorous.



This diagram shows a bud (4) in the axile between leaf petiole--the branch at the right--and the main stem- here cut lengthwise through the center. 1, the outer epidermis of the stem; 3, pith; 2, wood, which sends branches into the bud and the leaf. The line at five shows whêre an abscission layer will develop, causing the leaf to fall in the autumn.

The Vigorous Terminal Buds

The buds which occur at the end of the twigs are called "terminal." The terminal buds may be solitary, as on the common beech, or clustered, as on the oaks. Generally they are more vigorous than the axillary ones, and are the first to develop. In some plants they may be the only ones that develop. But if the terminal bud is injured in some way, or if its growth is arrested, then some or all of the axillary buds develop. In such plants, the terminal buds take the lead over the axillary buds, which are supposed to be kept back in their growth by the terminal buds.

The arrangement of the axillary buds along the stem is not a hit-or-miss thing, but a definite one. It proves to be valuable in identifying many of our trees and shrubs. The buds may occur in pairs, each exactly opposite the other, in which case the buds are said to be "opposite." Ashes, maples, and dogwoods show this arrangement. Some occur singly, in two rows, with the buds on one side alternate with those on the other. This is the case with the elm. Others occur singly and in a spiral path up the stem. This kind of arrangement is found in the poplars, beeches, oaks, hickories, and many other plants. It is rather uncommon to find more than two main buds at the same level on the stem. This does occur in a few plants, such as the catalpa, and in this condition the buds are said to be "whorled" (hwûrld). The arrangement of the buds and the relative vigor of buds in different positions are the main factors in determining the position and arrangement of branches, which in turn determine the general shape or outline of many woody plants.

The kinds of bud that a plant produces are of considerable importance. There are three principal kinds of bud. One kind is called the "leaf" bud; it develops into a shoot or stem with new leaves and new buds in their axils. Another kind is commonly known as the "flower" bud, and produces, upon development, a single flower or a cluster of flowers. Distinctive flower buds are present in cherries, peaches, walnuts, and dogwoods. Still another kind consists of leaves and

flowers in their formative stage and is termed a "mixed" bud. The apple, hawthorne, and shadbush have this type of bud. In many of our woody plants it is not very difficult to determine the various kinds. Leaf buds are usually slender in form; flower buds are plump; mixed buds are usually longer and thicker than the buds which contain only flowers or leaves.

Sometimes, in case of serious injury to a tree, as when the entire top or a large branch is cut or broken off, or when a large patch of bark is removed or the trunk or branch is ringed or girdled, shoots will start to develop below the wound. These shoots usually come from buds that have remained dormant for a number of years. They may no longer have bud scales, but remain merely as slowly-growing buds buried in the bark. Apparently the proper stimulus for the development of the bud has been supplied by the injury. Occasionally entirely new buds may be produced where there has been injury on a stem. These usually come from the cambial region. These buds are called "adventitious" (ăd'vĕn-tĭ'shŭs), and in some plants they occur frequently. The development of branches from both dormant and adventitious buds often gives rise to freakish-looking plants.

Photo by Spanish Tourist Information Office

From the width of the trunk it is easy to see that this tree is old. Its top is gone, but hidden in the old wood were sleeping buds which have grown to make the feathery young branches. A tree cut back to the trunk in this way is called a pollard.

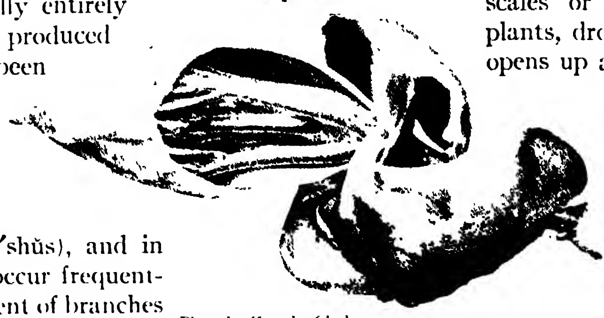


Photo by Cornelia Clarke

Here is an unfolding leaf bud of the hickory. You can see the young leaves wrapped securely in the protecting bud scales.

Buds are usually protected by structures called scales. But there are a few, such as those of the papaya—or papaw—which have no scales; and a few in which the scales are sparse and very tiny. Generally, however, scales are present, with or without other structures. The buds may be covered by numerous scales forming a shingle pattern, or simply by one or two visible scales that do not overlap. The buds of the willow are covered by single scales which look like hoods. The striped maple and black alder have only two bud scales, whose margins simply meet and do not overlap. The beeches and elms and oaks and cherries and many other plants have buds covered with numerous overlapping scales.

We generally think of bud scales as leaf structures. In certain leaves, such as those of the rose, small appendages occur at the base of the petiole. These structures are called stipules (stĭp'ūl), and are found in only a few mature leaves. Yet in the bud there are many leaves that have large stipules or scales at their bases, and in some plants these form the bud scales. To be sure, they are greatly modified, but all show plainly their characteristics. The leaf-base scales or stipules, in many plants, drop off after the bud opens up and begins to grow.

Very widely distributed, on both the outside and inside of buds, are hairs of various kinds. Sometimes they are silky and shiny and stiff; at other times they are short and bristly. Some have many cells, others but one. In the beech the leaves in bud bear long silky hairs which disappear soon after the bud opens. Sometimes these hairs are glands which give out gummy or resinous substances. The stickiness of the common horse-chestnut, the finish of the poplar bud, the resinous covering of many of the coni-

fers—especially the balsam—are due to such substances.

The bud scales, with the structures that go with them, protect the delicate growing point from drying out, as well as from being broken or injured by too much direct sunlight. The hairs, and the gummy and waxy and bitter substances, also partly protect the buds from insects and animals. These coverings do not protect the buds from cold, as many people have thought. The inside of even the large buds of the horse-chestnut, in spite of their outer gummy scales and inner woolly layers, quickly reaches about the same temperature as the air outside on cold nights. Buds do not keep up their temperature as do warm-blooded animals. When the shoot in the bud grows longer, the bud scales are usually carried along with it for a while, and the tiny young leaves are folded over the growing point. This gives continued protection to the delicate growing cells.

If the various parts of the bud are carefully taken apart, one by one, we find a definite arrangement of parts. In the narrow confines of a bud, the tiny young leaves are packed away in a manner which is characteristic for the individual plant or for whole, related groups. Poplar buds have their leaves rolled in toward the center like a scroll, while the willows are doubled in a simple boat-shaped form with the middle as the keel. The two halves of the leaves of the cherries lie folded at the midrib with the upper surfaces flat against each other. Beech, hornbeam, and some of the maples have young leaves closed up like a fan in folds. What a delicate hand it would take to replace and rearrange the parts of a broken bud, if one wished to place the parts together again as they once had been arranged!

There are certain peculiar buds with which all of us are well acquainted. They are buds which show an extreme development. Brussels sprouts, head lettuce, cabbage, and onions are only greatly enlarged buds. The bud scales and young leaves of these buds serve the plants as storage organs and also serve man as a food. Of course he has helped them to develop their great size.

None of us ever thinks of the succulent cabbage as merely a very large terminal leaf bud; yet that is what it really is.

Brussels sprouts, those firm little balls that are so like tiny cabbages, are buds that form in the axils of the leaves.

Reading Unit No. 23

DISEASES THAT SMITE THE PLANTS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The strange history of potatoes, 2–136
The terrible potato blight and how it affected mankind, 2–136-38
How the potato blight does its deadly work, 2–137-38
Other plant diseases and the damage they do, 2–138-41
How we fight plant diseases, 2–139-41
Plant diseases with alternate hosts, 2–141
Why the American chestnut tree was wiped out in our eastern states, 2–141

Things to Think About

What kind of organism ruined potato crops?
How can a plant disease cause untold misery to millions of people?
How does a parasitic fungus ruin a plant?
How was the valuable work of an important fungus killer discovered?
How does quarantine help us keep plant diseases under control?

Picture Hunt

How may we fight a plant's insect enemies? 2–136
What insects are reducing our food supply? 2–137
What is a common disease in the bean fields? 2–139
What should we do about barberry bushes if we are to save the wheat crop? 2–140

Related Material

Why are fungi which grow on our food plants dangerous? 2–55-74
Why are we concerned about plant diseases which destroy crops? 2–129
How can potatoes keep people alive? 2–31-32

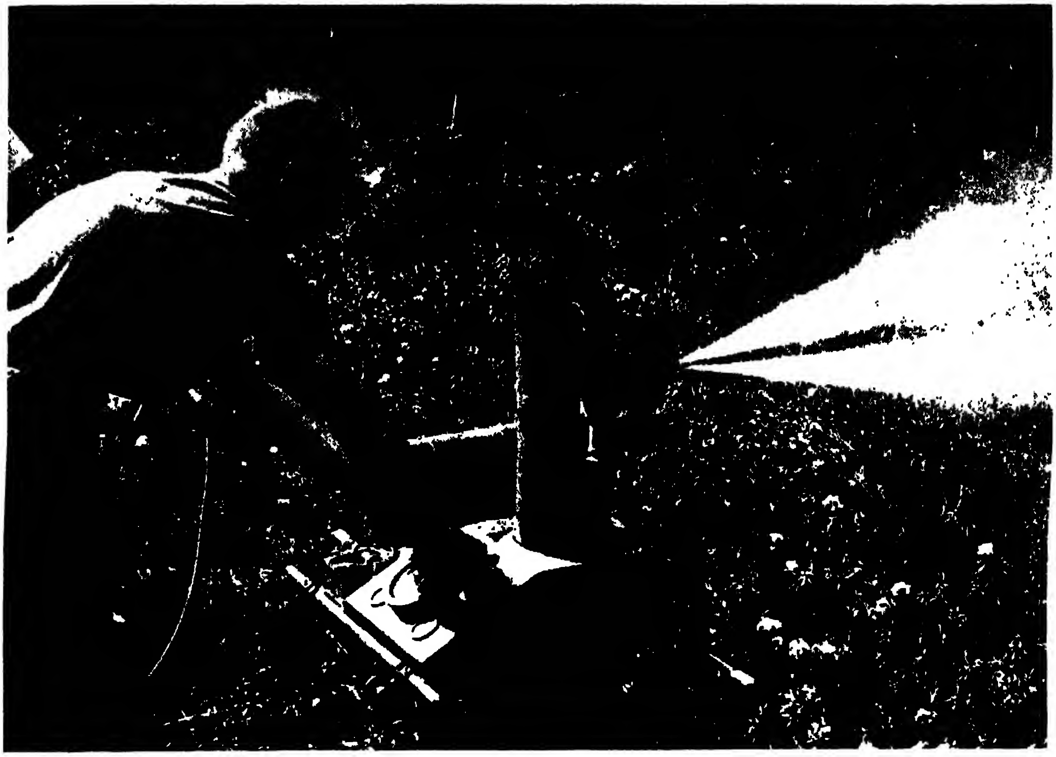
Leisure-time Activities

PROJECT NO. 1: Cut a slice of boiled potato. Put some iodine on it and observe the blue-black color. This color shows the presence of starch, a nutrient which provides energy.

PROJECT NO. 2: Find some dead chestnut trees in the woods.

Summary Statement

Not only insects but invisible fungi steal man's food. Fungi lack chlorophyll and therefore must get food ready-made. This necessity results in the death of many food plants each year; it causes tremendous losses and sometimes results in the death of thousands of people.



Canadian National Film Board Photo

On the shores of Lake Wagoose in southern Quebec the governments of Canada and the United States have set up an experimental camp in the heart of a great forest of spruce and balsam. Here scientists are trying to find out ways to wipe out the highly destructive spruce bud worm. Our picture shows a Canadian scientist spraying the trees with DDT, a powerful insecticide given to us by the chemists.

DISEASES THAT SMITE *the* PLANTS

They Can Take Many Different Forms, and Some of Them Are of Great Expense to Man

WHEN the first potatoes from America went over into France, the Frenchmen did not like them and would not eat them. So the King of France thought up a sly trick. He put a ring of soldiers around the potato field—to make the people think potatoes were something very choice. Then the people came at night to steal the potatoes. They ate some of them, and planted the rest.

From that clever trick came the potatoes that soon spread all over Northern Europe, where they grew to be the chief food of poor people, especially in Ireland and Germany. The Irish, above all, soon began to depend upon them, and the vegetables came to be called Irish potatoes. The plant really came from somewhere in Central or South America; and possibly from the same regions, a little later, there came another thing which was going to have a profound effect, not only on the potato, but upon our whole civilization.

That thing was the potato blight. A tiny fungus that no one can see without a microscope, this blight went over to Europe, quite by accident, just before 1840. At first it did not do much damage, and no one paid much attention to it. But it soon began killing whole crops of potatoes.

In 1845 and 1846 it was so deadly that it killed practically all the potatoes in Ireland. That meant ruin to the people, and nearly a

Photo by Cornell University

This is a field of potatoes showing the effects of the disease called "late blight." The plants at the right have been prematurely killed by the fungus causing this disease. The plants at the left were sprayed with bordeaux mixture, which protected them from the fungus. If this method of control had been known and practiced during the Irish potato famine in the middle of the last century, the loss in money would have been slight, and nearly a million lives would have been saved.

million of them starved to death. In the next ten years over a million and a half of the Irish left their own country for America. And this whole movement of population, with all the changes it meant to Ireland and to America, was mainly caused by a little organism less than a thousandth of an inch wide!

More Ravages of the Potato Blight

Potato blight was not confined to Ireland in that bad year, for it made ravages in Holland and in Germany too. From these countries also there was a vast emigration to America. Irish, Germans, Dutch, and even some Englishmen, nearly all of them good farmers, fled to the American shores.

It is certainly a powerful organism that will move millions of men across the sea. And as we shall see presently, there are other organisms that have equally changed the lives of whole peoples who could not run away. But first let us say just what these organisms are and how they cause disease among the plants.

In another story we have told how the fungi (fŭn'jī) reproduce by spores so small that they are measured in thousandths of an inch. The spores are so light that in many kinds they may be carried hundreds of miles by the wind, and so plentiful that the air and dust all about us is practically never free of them.

Nearly all the deadly plant diseases are caused by fungi or bacteria (băk-tē'rĭ-ȧ) which work inside the tissues of the plant. Bacteria and fungi also cause serious diseases in human beings and animals. What we see in the plant may be merely blotches or yellowing on the stems or leaves, but the real harm is being done to the tissue inside. In many cases the entire plant is killed.

The Food of the Fungi

The fungi do not earn their own living—they make no food of their own. They either steal their food from other plants, or else live on the dead remains of those plants. Those that cause diseases of plants are called parasitic (păr'ȧ-sĭt'ĭk) fungi. Sometimes, as in the potato blight, they infest any or all parts of the plant. Sometimes they chiefly attack special organs, such as the leaves or stems, the flowers or fruits or roots.

Some of the experts in plant diseases used to think that the spores could enter the plants and do their work only through small

injuries, such as we find in leaves that have been torn by the wind or bitten by insects. But it is now pretty certain that in some cases the tubes developing from the spores can get through perfectly healthy leaves to the tissue inside, where they can at once begin their work of destruction.

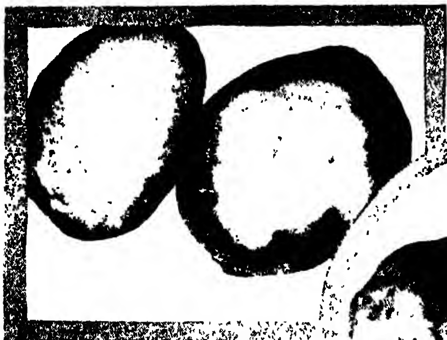


Photo by Cornell University

Here are some samples of the work of the potato blight. The same blight organism that destroys the top of the plant destroys the tubers also. The tubers shown above have been attacked by this disease, and so have the leaves, shown at the right. The dark spots on the leaves are the areas destroyed by the fungus. The small holes in the leaves were made by flea beetles.

When the tiny spores land on the leaf of their host and find enough moisture to work, they begin to sprout. They send into the interior of the tissue delicate threads which gradually spread all through the substance, living on the food they steal from the host plant. Eventually the fungous threads produce tiny spores again. Sometimes these are like the ones that first landed on the leaf or other organ, but sometimes they are very different; they may even be unable to grow on the same kind of plant, and have to live as a parasite on an entirely different kind.

Uncounted Millions of Disease Spores

The number of such spores discharged from a single potato plant, for instance, is enormous—certainly many millions—and they are at once carried by the wind to neighboring plants, where they repeat the process.

With uncounted millions of disease spores flying through the air all the time, we may wonder why there are any crops left. For there are diseases for nearly every staple crop. Corn, wheat, rice, bananas, sugar, chocolate, coconuts, yams, and all our vegetables have fungous parasites that attack them. Many of these pests would wipe out the crop if they could work unchecked, and in fact some of them have done so. Moreover, from time to time new blights appear and for a while have free sway.

But Nature and science working together can sometimes check them, or at least reduce the loss they cause. In spite of all our efforts, however, plant diseases still kill crops worth hundreds of millions every year. In some years, when very severe epidemics cannot be checked, the loss may be far greater. In 1916, an especially bad year, one single rust disease ruined over $250,000,000 worth of wheat, with widespread distress to the farmers in the United States and Canada.

But bad as the case is, it is not hopeless. After all, fungi are just as much plants as the ones they destroy. They need special conditions of moisture and temperature in order to do their work of destruction. Often they do not get what they want, and then millions of them perish. Possibly a single sunny, windy day, followed by a night of little or no dew, may mean that a whole crop is saved—just because the fungus spores could not find enough moisture to sprout.

Then, too, many of these fungi are rather limited in the kinds of crop they will attack. They can work only on the particular tissue for which they are fitted. Tobacco diseases never attack corn, for instance; and wheat is immune to the spores of the clubroot

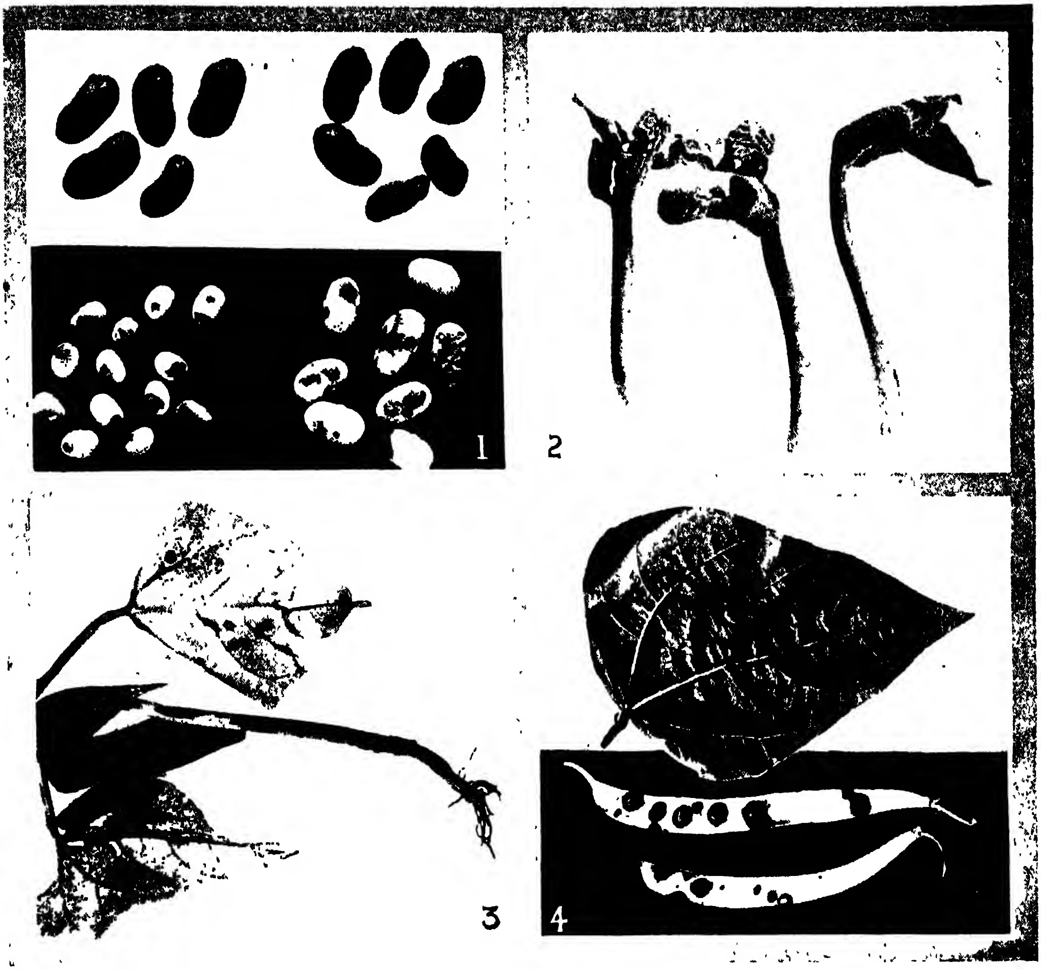


Photo by Cornell University

These pictures show some of the results of bean anthracnose (ăn-thrăk'nōs), a disease that causes great damage to the bean crop. All the beans in photograph number 1 have been attacked by it and show the spots that it leaves. The young seedlings in photograph number 2 show the disease spots on the cotyledons. The young plant in the third photograph shows anthracnose spots on the stem and leaves. And the same fungus has attacked pods and leaflet shown in the fourth photograph. Notice the dark coloring along the veins of the leaflet. Anthracnose is common in plants, and is caused by a number of different fungi.

disease of cabbage. Nature keeps the countless millions of disease spores in certain great armies, divisions, and regiments, each of which can have only one object. But for this fact we should all starve, for not a single major food crop would be left.

The scientists have found out a great deal more about these pests. They know that the fungi cannot stand a spray made with certain chemicals. They have experimented with these sprays in their laboratories, and have sent them out in millions of gallons to the farmers. They have made machines to cast a spray as fine as a fog over whole fields in a few hours. They have sent airplanes to fly low over cranberry bogs or cotton fields and to release clouds of poison dust that will kill or check special diseases of these crops.

One of the most effective of these fungicides (fŭn'jĭ-sīd), as the sprays and dusts are called, is "Bordeaux mixture." This is so named because it was discovered near Bordeaux, in France—quite by accident. In 1882 some French grape growers were troubled by thieves, and began to sprinkle the vines nearest the road with a solution of blue vitriol (vĭt'rĭ-ŭl) and lime. This gave the plants a milky-blue appearance; and the

thieves were afraid to eat the grapes. But it did something vastly more important. For the growers noticed that the vines that had been sprayed with the mixture were almost free of the "downy mildew," a serious disease of the grape.

Such a lucky accident led to other experiments, and by 1885 the first scientific formula for the mixture was published. It is made of water, lime, and blue vitriol, or copper sulphate, and it is now used throughout the world. No one knows how many hundreds of millions of dollars this spray has rescued for the farmers and gardeners. It is especially valuable on garden vegetables and on fruit trees.

Photo by U. S. Dept. of Agriculture

The wheat rust, one of the worst of plant diseases, was impossible to control until we discovered that the fungous growth which causes it has to spend part of its life on barberry bushes. Here is an enlarged picture of part of a barberry leaf to which is clinging wheat-rust fungus in the well-named "cluster cup" stage of its development.

Other sprays and powders are constantly being discovered in the fight against plant diseases. The plant breeders, too, have done wonderful work in finding varieties of crop plants that are immune to special diseases. But many crops would be lost if the scientists did not put up a steady fight. And in spite of everything, there is still a huge loss. The following estimated figures, chosen at random from a long list, show what the loss may be in a single year:

Crop	*Loss*
Wheat	190,000,000 bushels
Oats	78,000,000 bushels
Corn	200,000,000 bushels
Potatoes	80,000,000 bushels
Sweet potatoes	58,000,000 bushels
Apples	18,000,000 bushels
California grapes	$ 10,000,000
Cereals (Germany)	$100,000,000
Wheat (Australia)	$ 12,000,000

Of all the diseases the rusts on grain are perhaps of most importance because grains are so widely used. For hundreds of years no one knew how to control or check these pests. But science discovered a way when it found out the peculiar life histories of the fungi causing grain rusts and learned where the spores come from that cause the disease.

The rust on wheat is a parasitic fungus which kills the plant and produces the rust-colored streaks and spots from which the pest gets its name. There are other varieties on oats, barley, and many other grains. The life history of this tiny organism is by no means so simple as that of the one causing potato blight. The blight spends all its active life on the potato plant, but the wheat rust does no such thing.

Years ago scientists observed a rust on the common barberry of Northern Europe. This plant was introduced into American gardens as an ornamental shrub, and the rust on it seemed to be a comparatively innnocent disease. No one paid much attention to barberry rust, though it did seem odd that its spores did not germinate on barberry leaves.

A little later it was found out that only the summer spores of wheat rust germinate on wheat. Of course this would mean that the disease should not be carried over the winter; and yet everyone knew that it carried over very well indeed. Where could be the explanation? Could it lie in the barberry? The thing hardly seemed likely, but many things look unlikely enough until we find out that they are true. It had been repeatedly observed that there was some relation between the development of wheat rust and the presence of barberry bushes, especially to the windward side of diseased areas. Eventually the truth was recognized that the rust spores from the barberry plants produced rust on the grain.

For barberry rust and wheat rust are not

two separate organisms, but simply two stages in the life history of a single one. Probably for thousands of years that organism has spent half its life on barberry and the other half on wheat. It needs both plants to complete its life cycle. To the barberry it has always been comparatively kind, but what it has done to wheat you can see from the table on the preceding page.

Plants with "Alternate Hosts"

Once this double way of life was known, a shout of joy went up from the scientists. For if the pest really was one organism which had two homes, the remedy was easy - simply to take one of its homes away from it. And now millions of barberry bushes have been burned up, and many wheat-growing regions have laws against their cultivation.

Several fungi with this way of life are now well known. For years they were a complete mystery, but to-day we know they have what we call "alternate hosts." Besides the wheat-barberry pest, there are two others that cause diseases of importance. One grows on white pine trees and gooseberry bushes, and causes what we call the "white-pine blister rust." Another grows on relatives of the apple and on cedar trees, causing the peculiar "witches brooms" and "cedar apples" on the cedars Still others attack spruces and firs

Why There Are Plant Quarantines

Some of the diseases are so serious and so difficult to control that there is danger of destructive crop losses following their introduction into a country. To prevent or reduce such accidental introduction, the government has established plant quarantines at ports of entry. All foreign plants are refused an entry if the quarantine specialists can detect the slightest evidence that the plant is diseased. And most plants are forbidden entry at all, because of the possibility that their diseases are of the kind that might easily escape detection. One such disease, imported before the quarantine was started, has been disastrous.

Its spores are carried by the wind, and after landing on a chestnut branch they begin to grow. They get under the bark, eat into the tissue, and finally girdle the branch. That kills the whole branch above the diseased portion. And even this is not the end. The fungus keeps on growing, spreads to the main trunk, and finally kills the tree. It has killed practically all the chestnut trees in Eastern North America.

There seemed to be no way to save them. The state of Pennsylvania, seeing its fine chestnuts doomed if the blight could not be stopped, took drastic steps. A path was cut from one boundary of the state to the other, removing every chestnut tree. The people thought that if this path was made wide enough the spores would never jump it, for they knew that the spores could not live on any other kind of tree.

The Doom of the American Chestnut

Anxiously the Pennsylvania authorities watched the chestnut blight creep across New Jersey and over the Delaware River. Then it struck Pennsylvania's band of chestnut-free country, in the eastern part of the state. For a year or two it stopped, and all seemed well. But one summer the blight jumped the barrier in several places, and the scientists knew they had lost their fight. To-day there is scarcely a living American chestnut tree in the eastern states.

One may wonder where such a destructive disease came from. It is very probable that it came with some Chinese or Japanese chestnuts that were shipped into the country. These Asiatic chestnuts are not seriously injured by the disease. They have been exposed to it for many hundreds of years, and only those that are immune, or able to resist it, have lived. The American chestnuts, on the other hand, had not developed this resistance, and have been killed off. Scientists are on the watch for possible American chestnuts that may have been able to resist the disease. If any such trees exist, they may start a new resistant race of American chestnuts.

We believe that man and Nature working together ought to be able to control plant diseases, but we as yet have a long way to go.

Reading Unit No. 24

PLANTS WITH ONE SEED LEAF

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What are monocotyledons? 2–143-44
Pollination in monocotyledons, 2–144-45
Cat-tails, 2–145
Characteristics of grasses, sedges, and rushes, 2–145-46, 148
Strange methods of pollination, 2–148-49
Palms and pineapples, 2–150-51
The arum family, 2–151
The lily family, 2–151-52
Orchids, 2–152

Things to Think About

What are the characteristics of a monocotyledon?
Why is it necessary for wind-pollinated plants to produce enormous quantities of pollen?
What grasses furnish food for man?
How does the odor of skunk cabbage help the plant?
What are some common members of the lily family?
Why are orchid flowers intricate and beautiful?

Picture Hunt

How are cat-tail seeds spread far and wide? 2–143
What are three important characteristics of monocotyledons? 2–144
How can you recognize a monocotyledon by its flower parts? 2–146-48
To what group of plants does the coconut belong? 2–149
What is an epiphyte? 2–150

Related Material

How are pineapples grown? 9–185-86
How does mankind use corn? 9–104-6
Why is wheat the world's most important plant? 9–97-102

Leisure-time Activities

PROJECT NO. 1: Using a knife, cut some slices out of a corn stalk or other grass. Use a lens to learn how the vascular bundles are arranged, 2–144.

PROJECT NO. 2: Count the number of petals and stamens in such flowers as the lily, tulip, trillium, smilax, Solomon's seal, dog-tooth violet, spiderwort, and bellwort. Are they monocotyledons? 2–144

Summary Statement

Monocotyledons are herbs with only one seed leaf in the embryo; parallel-veined leaves; flower parts in threes, and scattered bundles in a pithy stem. This group includes such plants as grasses, sedges, rushes, lilies, palms, pineapples, and orchids.

Photo by Cornelia Clarke

Cat-tails growing as close together as these make a thick matted tangle of their leaves in many a marsh and along many a sluggish stream. The leaves of this simple monocotyledonous plant are straight and stiff, altogether typical of the leaves of monocotyledons. The flower clusters are the stiff brown "cats' tails" that give the plant its common name. Later the tiny seeds will break away and float off in the air.

PLANTS WITH ONE SEED LEAF

What is a "Monocotyledon"? This Will Give You the Meaning of the Long Word and Tell about the Important Plants That Bear the Name

IF YOU saw a puzzle picture with palms growing on icebergs, grass on an apple tree, and beautiful lily flowers coming out of a head of cabbage, you would think it was all very silly. You know that palms grow only in the warm climates and grass only in the ground; and that cabbage has no flowers like a lily's.

For we usually have a store of general information that we remember without thinking. The moment we see something unusual, like the puzzle picture, we know it does not agree with our general knowledge of the grasses, lilies, and palms. But why have we mentioned the grasses, lilies, and palms all together? Why do we not associate them with beans or peaches or maple trees? The real reason is that, however different the various grasses, lilies, and palms may look, they all have some important characteristics which are much alike. We are now going to see what those characteristics are.

They are all members of a great group of flowering plants that has a very big name. We call them "monocotyledons" (mŏn′ō-kŏt′ĭ-lē′dŭn). "Mono" means "one," and "cotyledon" means "seed leaf"; and all of these plants are alike in having just one seed leaf. All of these plants, and all of their relatives which we shall mention presently, have only a single seed leaf and not a pair of seed leaves, as have the "dicotyledons," such as the bean or squash.

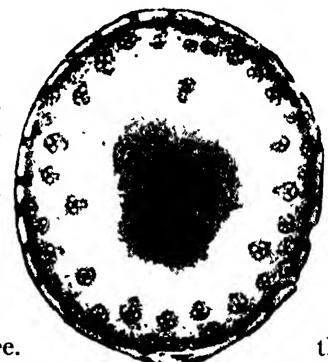
This leaf of the day lily shows plainly how its veins run parallel to each other, in the way characteristic of the monocotyledons.

There are a great many monocotyledons. In fact, they make up one of the main groups of flowering plants, with thousands of different kinds gathered into nearly fifty separate families, of which the grasses, lilies, and palms are merely three. In addition to having a single seed leaf, the monocotyledons have several other charactersitics in common.

Here again we see a characteristic of the monocotyledons—a flower with its parts in threes. There are three petals, and the stamens, whose anthers look like black dots in the picture, are six—twice three—in number. The flower is a spiderwort.

Nearly all of them have the veins in their leaves running side by side from one end of the blade to the other. In other words they are parallel-veined. You may see this in any grass, lily, or palm. Nearly all of them have the parts of their flowers in threes or in multiples of three. There may be three petals, sepals, or stamens, or there may be six or nine or even more; but there rarely are four or eight, or five or ten, as in certain other plants, such as the roses. What is more, only a few of the monocotyledons are woody. Those which are woody, mostly palms and bamboos, have no heartwood or sapwood or bark, as has an oak tree, for they do not have a regular cambium. Instead they may have an outer rind and a pithy or hollow stem, such as you may see in cornstalks or in grass stems. And there are still other structures that set this great group of plants off from any other. But to fix the main things in our minds before going on to something further, let us set down a little table of the most important features of the whole group. Monocotyledons are plants which:

1. Have only one seed leaf,
2. Usually have parallel-veined leaves,
3. Usually have the parts of their flowers in threes or multiples of three,
4. When they are woody, have pithy or hollow stems with a hard outer rind, but no heartwood, sapwood, or bark.



Photos by Cornelia Clarke

In this cross section of a stem of timothy grass we see still another characteristic of the monocotyledons, in that the vascular bundles are scattered instead of being in a single ring.

To make it easy to know one from another, all the thousands of monocotyledons have been arranged in big families. Most of these we know by sight, just as we do the grasses, lilies, and palms. To know them all is quite impossible, but the main ones can easily be listed. And the list is an important one for us, because the plants in it give us many of our most beautiful flowers, most of our cereal grains, and various other things, as we shall see.

Of course plants without conspicuous flowers rarely have any insects visit them and carry off their pollen. Now thousands of the monocotyledons, such as the cattails, grasses, sedges, and rushes, have no

colored petals at all. They are all true flowering plants and produce much pollen, but the pollen is carried only by the wind, and never by insects. The wind is a very wasteful carrier. For one grain of pollen that it takes to the right place, in another flower, it carries thousands of grains to places where they will never do any good.

Other monocotyledonous plants have developed other methods of pollination. Some have developed beautifully colored flowers, like the lily, iris, and orchid, whose pollen is carried by millions of insects. The insects may do far better than the wind, because they fly straight from one flower to another. So a plant with a flower that attracts insects has a far better chance than one without such a flower, especially if plants are far apart. "Wind-pollinated" and "insect-pollinated" plants are found all through the monocotyledons today, many of them very important to us. Some kinds, such as wheat, barley, and rye, are usually self-pollinated. When self-pollination occurs, neither insects nor wind nor other agents are necessary to carry the pollen from one flower to another.

One of the simplest monocotyledons is the common cat-tail, which covers miles of marshy land all over the world. It is a great reedlike herb with thick rootstocks creeping in the mud and sword-shaped leaves that are often six feet long. It grows so densely that it is hard to push your way through a cat-tail marsh.

You will never wonder where it got its name if you know its close brownish spike of flowers at the end of a stalk that tops all of the leaves. It looks more like the stiff tail of a cat at the end of a slender pole than like a group of flowers. The brownish spike, which some people call "candlewick" and others "water torch," is not really a single flower, but a compact cluster of flowers. It contains thousands of very simple and small flowers, without conspicuous petals or sepals.

Photo by Cornelia Clarke

The grasses, sedges, and rushes have flowers very different from the gay blossoms we usually mean when we speak of "flowers." Here is the modest flower cluster of a sedge.

If you pick the spike apart, you will see that the flower consists of only a few bristly hairs, which is all the cat-tail has for sepals and petals. They do not seem to be of much use, but later on they help the tiny seed to float through the air.

Of course it could not be a complete flower if it had nothing but bristles. There must be stamens and pistils in it somewhere. And so there are, but not in the same flower. All the stamen-bearing flowers are in the upper part of the spike, and the pistil-bearing ones below it. When the stamen-bearing flowers are ready to shed their pollen, the wind alone helps to carry it, and it is the wind that will later carry its hairy-plumed seeds, which will develop into new plants.

Besides the cat-tail there are only three big families of monocotyledons which have developed wind-pollination—the grasses, sedges, and rushes. Many would say they are all "just grass," for they do look a great deal alike, and all of them have grasslike leaves. But to say this is just as careless as to say that a radio, a phonograph, and a telephone are all "just talking machines." They are, but with great differences; and yet their differences are no greater than the differences between a grass, a sedge, and a rush.

Wheat, corn, barley, rice, bamboo, and the turf in your lawn are all true grasses. Their inconspicuous flowers are all packed away between tiny scales, known as "glumes" (gloom), several of these scales being arranged to form a spike. And these spikes

This flower is called a grape hyacinth, but it is related to the lilies and not to the grapes. Its flowers are blue. Its petals grow together in a tight little cup, but the cup has six—twice three—teeth, in typical monocotyledonous style. This flower was brought to America from its home in Europe.

Photos by Cornelia Clarke

Above and to the right we have two more true lilies. Above is the Turk's cap lily. It is an exceedingly handsome flower, with bright red and black spots and brown stamens.

And this is the familiar tiger lily, another gay flower. Its corolla is orange-red spotted with purple. Both the tiger and the Turk's cap lilies get their fanciful names from their bright colors.

are gathered into various sorts of clusters, which make the plumelike tassels we know so well in the grasses. But there are no petals or sepals present in the flowers.

How we get food from them, and water pipes and citronella oil, and paper and hats and many other things, you will find in our special story about the grasses. Here we must only look again at their leaves and stems to see how they are different from the

PLANTS WITH ONE SEED LEAF

Surely one of the most beautiful of flowers is the "Easter lily," whose pure white blossom most people think of first when they say "lily."

Here is another true lily, a cultivated kind with speckled petals that curl backward. Its Latin name is *Lilium speciosum rubrum.*

Photos by Cornelia Clarke

The dainty cups of the lily of the valley are made of six petals fused together. This is not a true lily, but is closely related to the lilies. Of course, it is one of the monocotyledons.

The trillium, or wake robin, is a close relative of the lily of the valley; neither is a true lily. The trillium is a spring wood flower, which, true to its name, has petals and sepals in threes.

Photo by Cornelia Clarke

This beautiful little flower is so starry and white that it has been named the star-of-Bethlehem. It is a lily whose six-petaled corolla is pure white above and greenish white on the under side. It blooms in the early spring. Its native home is Europe, but it is now seen often in America as well.

sedges. Nearly all grasses, except corn, have hollow round stems, closed at the joints, but the sedges and rushes never have this.

When Moses was found in the bulrushes, his basket was really floating among a clump of sedges. There are hundreds of different kinds of sedge, and they look so much like grass that many people mistake them for it. But their stems are always triangular and solid. They do have narrow sheathing leaves like the grasses, but the sheath is tightly closed, while in the grasses it is always split and is overlapping.

How Sedges and Grasses Differ

It is surprising to find what is the relative value of these families as a source of food. Most of our staple foods come from the grasses, but not one from a sedge. For grasses have a rich starchy grain, while the sedges are used only to make matting. The grasses furnish all the cereal foods of the world.

Grasses and sedges, then, are really quite different if we take the trouble to look at them closely. Both agree in having wind-pollination and very inconspicuous flowers with no petals or sepals, but their leaf sheaths, stems, and fruits are very different.

Still another group of grasslike plants may be mistaken for either of them. These are the rushes. The only exact way to tell a rush from a grass or sedge is to look at its flowers. They are mostly in more or less compact clusters, and instead of having well developed sepals and petals, they have six scalelike structures which represent sepals and petals. Rushes have grasslike leaves, and often grow in tufts in marshy places. Some kinds cover many square miles of our salt marshes, and one kind is the chief source of the "salt hay" used for packing china. But like the sedges, which they resemble in their habit of growth, they give us no foods. Their chief interest to us lies in the fact that in their flower development they seem to have gone a step further than have the grasses and sedges. So plants like the rushes, with their scalelike sepals and petals, seem to be pointing the way for the rest of the monocotyledons, which gradually lose the habit of accidental wind-pollination for a more certain arrangement.

Strange Adventures of a Grain of Pollen

Changing from wind to insects as pollen carriers was not a quick process. Other methods of pollination have also been developed by these plants. One of these methods is water pollination. A special kind of pollen is developed, which can live all its life in the water and float from one

Photo by Brown Bros

Coconuts are one of the most important products of the palm family, and one of the most familiar. Here are great groups of them floating to market. The outside coat of the coconut fruit is so thick and fibrous that the coconuts can float a long time without allowing the water to enter and hurt them.

submerged plant to another in doing its work. Several hundred monocotyledons, such as the pondweeds, the laceleaf, the wild celery, the sea wrack, and many others, are thus true water plants with this means of pollination. The tale of how they live and of what happens to their pollen is one of the most interesting in the plant world.

But perhaps the strangest of Nature's experiments was with snails. In a few close relatives of our common jack-in-the-pulpit, found in the East Indies, the pollen is carried by snails. Snails and water, however, are not the surest means of carrying pollen. For all the plants we are now describing have more or less showy flowers, and this means myriads of insect visitors to carry the pollen from flower to flower.

Photo by American Museum of Natural History

Here is an avenue of royal palms, very proud and stately. You will notice that though they are very tall these palms have no branches, but carry all their leaves in a crown at the top. When monocotyledons grow tall they do not thicken or branch as dicotyledons do, for their stems are different.

The story of all the monocotyledons that have their pollen carried by insects would fill all the books in this series. For these plants include many with showy flowers, like the lily, iris, amaryllis, all the orchids, and thousands of others. Some of these are very old friends of ours, but many others we may not know so well.

Everyone knows the feathery-leaved palm of the florist shops; it is only one of a huge family of over 1,500 different kinds of palm. About half of these have leaves like those of the common fan. Nearly all of them have some sort of trunk, and in the

Photo by N. Y. Botanical Garden

The soft, gray-green "Florida moss" that drapes this old tree so heavily is not a moss at all but a monocotyledon of the pineapple family. It is an epiphyte; that is, it grows on other plants, as it is growing on this tree, and gets its water directly from dew, rain, and fog.

beautiful "royal palm" the trunk may be over a hundred feet tall. Others, like the palmetto of our southeastern states, are much shorter. There is always a large flower cluster up among the leaves, and in one Brazilian kind the cluster may weigh over a hundred pounds. Later most palms bear a fruit, the one we know best being the coconut. Many uses have been found for palms, and they form a magnificent part of many tropical forests.

Before Columbus came to America, no white man had ever seen a pineapple, for the pineapple and about 850 of its relatives are found only in North and South America. While the pineapple grows in the ground, most of its much more gorgeously colored relatives grow only in the air. These air plants, or "epiphytes" (ĕp'ĭ-fīt), are so commonly fastened to the bark of trees, and even to telegraph wires or the roofs of barns, that tropical America seems festooned with members of the pineapple family. They are mostly without stems, and many of them have a rosette of beautifully colored leaves, often rather prickly on the margin. From this rosette, which often holds a good deal of water and breeds many mosquitoes, comes the flower stalk. In most species this is crowned by very brilliantly colored flowers arranged in variously branched clusters. The pineapple itself is the only one with a fruit good enough to eat, most of the others having a dry or inedible fruit. The leaves in one sort, the "pita" (pē'tȧ) of tropical America, give us a fine fiber, but almost the only one to grow in the United States is the "Florida moss." It is not a real moss, but a member of the pineapple

Photo by Cornelia Clarke

Here is our old friend the green striped jack-in-the-pulpit. If you have ever been in one of those churches where the pulpit has an overhanging hood above and behind it, you will agree that "jack" is well named. There are many other flower clusters built somewhat like this, with a group of flowers at the base of a club-shaped stalk, all surrounded by a showy spathe, which looks like a petal but is not one.

family, its gray foliage festooning trees in much the same ways as a lichen or a moss will decorate branches.

While every country boy knows the common jack-in-the-pulpit, few of them know that it is just one of a family of over a thousand relatives, ninety per cent of which live in tropical forests. Nearly all of these have a bitter or poisonous juice, and in one of them, the "dumb cane," the juice will paralyze your tongue so that you cannot speak. Many of them, like the jack-in-the-pulpit itself, break the rules for monocotyledons by having netted-veined leaves, and all of them have very curious flowers. These are very small, and are crowded on a stalk called the "spadix" (spā′dĭks), often covered by the pulpit, which is called the "spathe" (spāth).

The skunk cabbage, which belongs to this family, smells fairly sweet as compared with many other flowers in this group. They smell so bad that only insects which are attracted by disagreeable odors will come to carry off the pollen; and there is the one in the East Indies which has to rely on snails.

Though the leaves have a bitter juice, they are often very handsome, especially in the common elephant's-ear and in some greenhouse relatives that we grow as foliage plants. The fruits are rich and sugary in the tropical breadfruit, which has huge leaves with holes scattered in them like the holes in a Swiss cheese. Many of the plants are called "arums" (ā′rŭm), and the family is often called the "arum family." Some of the tropical kinds, especially the "taro" (tä′rō), have so much starch in their roots that they are used as food. But the natives have to be very careful to heat or roast the roots, in order to drive out the poison which is so common in these plants.

Photo by Cornelia Clarke

These are spikes of Roman hyacinth, another of the countless beautiful flowers of the monocotyledonous plants. This colorful and fragrant flower never grows wild in America.

Besides the lily itself, the huge lily family contains over 2,700 different kinds of plants, none of which give us important foods except the asparagus and the onion. There are useful fibers in the leaves of the New Zealand flax and in some of the Spanish bayonets, both of which have long sword-shaped leaves that are used in making rope. In Africa the natives make the finest bowstrings from another plant of the lily family, the bowstring hemp.

Photo by Cornelia Clarke

Among all the flowers of monocotyledons the orchid is the most amazing. It is one of the most elaborate of all flowers. This particular orchid is a Cattleya, which does not grow wild in America but is often sold by florists.

But the thing most people like about the lily family is the beautiful flowers of such old garden favorites as the lily of the valley, the tulip, the hyacinth, the squill, the tiger lily, and the red-hot poker. And among

the wild flowers who does not know the dog-tooth violet, the trillium, the star-of-Bethlehem, the grape hyacinth, and the Solomon's seal? Even the foliage of some, such as the butcher's-broom, the dracaena (drȧ-sē′nȧ), and the smilax (smī′lăks), we use for decorating our homes.

Strange Plants of the Lily Family

Most plants of the lily family have some sort of bulb, as in the onion or the tulip, and die down to the ground for the winter. But there are tropical kinds that have tall woody trunks. Perhaps the strangest are the tall Joshua tree of our own Southwest and the dragon tree of the Canary Islands. We should never suspect that this belonged to the lily family at all, for it is much larger than most of the plants of this group.

Many of the monocotyledons, including the lily family, have perfectly regular flowers. No flower is lop-sided, or has a twisted or one-sided corolla (kô-rŏl′ȧ). If you look closely at a tulip flower you can see how regularly bell-shaped it is. But other families have developed flowers that are not regular at all. They are one-sided, or twisted, or have an upper and lower lip to the corolla. You may see this in a gladiolus flower and in many other plants in the iris family, in most of the plants of the banana family, and in a few of their relatives. Some people think these irregular flowers are so constructed as to allow only one particular kind of insect to carry the pollen. For many insects steal pollen without doing the work of carrying it at all. Whatever the cause, flowers with different shapes were developed, and in the end a whole group of families with irregular flowers was produced. The largest of these are to be found in a huge family with some of the most curiously irregular flowers on earth. These are the orchids.

Exquisite, Colorful Orchids

The orchids (ôr′kĭd) have the most highly specialized flowers, the most complex, and much the most beautiful of all the monocotyledons. Perhaps you know them only from the brilliant purple-fringed orchid of our swamps, or the exquisite Cattleya (kăt′-lē-ȧ) in the florist's window. But there are altogether 7,500 different kinds, spread all over the world, with by far the greatest number in the Tropics. All of them are true herbs—they do not have woody stems. Those of temperate regions grow in the ground, while nearly all the tropical sorts live as air plants attached to the bark of trees.

Flowers that look like butterflies, like dragons' heads, or like a snake's mouth, and flowers in hundreds of other weird shapes are the usual thing in orchids. Some of them, like our beautiful arethusa (ăr′ē-thū′-sȧ), with its fringed beard, grow singly; but many orchid flowers grow in large clusters, some of them branched and many feet long. So curious and marvelously colored are they that people have gone all over the world hunting orchids, and a single plant of a rare variety is of great monetary value. Since a large number of the finest kinds grow up in the tree tops, several orchid hunters have been killed trying to gather these most precious of all the monocotyledons.

The Oddly Shaped Orchid Flower

The flowers are so irregular that it is hard to separate the sepals and the petals in them. They do have a floral plan, for there is nearly always some kind of "lip," caused by the twisting of one petal, and there may be one or more fringed beards or long drooping streamers. But they are so very irregular that some kinds look more artificial than any ordinary flower.

The arrangement of all the many kinds of orchid flowers is so intricate that Charles Darwin spent years studying them. He found that these curiously-shaped flowers are often arranged so that only one particular variety of insect visitor is welcome.

We have seen simple wind-pollinated cattails, followed by the grasses, sedges, and rushes. Then came the water-pollinated or snail-pollinated plants. Finally, after thousands of regular flowers with insect pollination had developed, came these marvelous orchid flowers—the most intricate of the monocotyledons.

Reading Unit No. 25

HOW DOES A VINE GRIP A WALL?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Where tendrils occur, 2–154
What tendrils do for the plant, 2–154-55
Why tendrils move about, 2–155
How to tease a tendril, 2–155
How tendrils anchor plants, 2–155

Things to Think About

How do vines climb?
What makes tendrils twist about?
What happens to tendrils coiled about a twig?
How are Virginia creepers anchored to the bark of a tree?
What do motion pictures teach us about tendrils?

Picture Hunt

What well-known plant has tendrils? 2–154
What vine has special tendril tips for anchorage? 2–154

Related Material

How did Charles Darwin learn so much about plants and animals? 13–434-37
How long may a wild grapevine grow? 2–263
What are lianas? 2–263
How does the dodder overpower a plant? 2–56-57
Where can we find the oldest grapevine? 9–165
How does a tendril get thicker? 2–30

Leisure-time Activities

PROJECT NO. 1: Look carefully at a vine growing against a house to learn how it clings to the walls. Include such vines as Boston ivy, English ivy, Virginia creeper, and sweet pea.

PROJECT NO. 2: To learn how tendrils anchor a plant, repeat the experiment with young tendrils, 2–155.

Summary Statement

Vines are plants which do not seem able to stand erect unless their tiny tendrils coil about twigs or act as suckers against a wall or tree. These tendrils wave about in all directions until they touch something solid which they can attach themselves to. Vines include such plants as grapes, sweet peas, Virginia creepers, and others. In the tropics vines often grow to be hundreds of feet long.

Photos by Cornelia Clarke and Walton Co. C. of C., Fla.

This grape vine is supported on a frame, but when the grape grows wild it finds its own supports and clings to any sturdy shrub or tree that its tendrils happen to reach. In the circle we see the tips of the especially formed tendrils of the Virginia creeper. In this plant the tendril does not curl around a support, but clings closely to it by the tendril tips, which act as suckers.

HOW DOES *a* VINE GRIP *a* WALL?

This Will Tell You How Its Delicate and Sensitive Tendrils Help to Keep the Leaves in the Light

WE KNOW that almost any animal is irritable when we touch him with some sharp point, like the end of a lead pencil, though we do not often think of plants as being irritable too. But if you want to see whether a plant can be irritable in its own way, you might just try your pencil sometime on the young tendril of any plant that grows one.

The tendril seems to be one of the most sensitive parts of a plant—that is what its name means—and no wonder it is so irritable. On the grapevine, where we know them best, the tendrils are at first so soft that we can easily chew up their slender, slightly acid little runners. Most of the tendrils are found on vines of one sort or another; in climbing plants they help the stems to catch hold of any support that can be found, and so climb up in the world. Very few of the tendrils are true stems, though they happen to be such in the grapevine. They are mostly outgrowths from the leaves of the plant, even if their little threads do not look at all like leaves.

Whether it grows from stem or leaf, you will always know a tendril when you see it. In common garden peas, for instance, you will find many of the fine, green, threadlike organs, usually coiled around some support or seemingly looking for some support to coil around. It is because they always want to coil around something that the tendrils are a help to plants that need to climb up into the sunlight. The plants that we call "tendril climbers" are most numerous in tropical forests, but we have plenty of them in our own woods and gardens—grapes, peas, pumpkins, Virginia creepers, passion flowers, and still others.

These tendrils are most irritable when they are youngest and softest. After a time, when they turn harder, they lose most or all of their power of being irritated. In fact, they change a good deal as they grow older, and the interesting things they do led Charles Darwin to study them for years and finally to write a book about "The Movements and Habits of Climbing Plants."

How Tendrils Change Their Form

Being so irritable, the tendrils have a great deal of the power—common to all living creatures—of altering in form and growth when any unexpected thing provokes them. This is very easy to see in the tendrils, if you are willing to tease them a while and watch what happens.

Even when there is nothing to touch them, tendrils and the growing shoots of climbing plants are constantly swaying about. The movement has nothing to do with the wind or sun, for it will go on in a dark room where there is no breeze. Of course the wind often blows the tendrils about, but that is only an interruption of their own natural motion. The cause of this motion is an unequal growth of the cells on different sides of the tendril or shoot. If motion pictures are taken of young tendrils or growing shoots, with each exposure several minutes or even hours apart, and if the film is then run rapidly through the projection lantern so that the rate of movement seems speeded up, the movements of tendrils and shoots appear startlingly rapid and lifelike. If they meet any suitable thing in their way they will coil tight around it and hold fast. Once they are well coiled around it, they harden and get stronger. Then they are not irritable any longer.

How to Tease a Tendril

But if you want to see how irritable they can be at first, just get out your pencil and muster a little patience. Find a passion-flower vine and hold your pencil near the tip of one of its tendrils. Hold the pencil quite still, just as if it were the twig of a tree; in a very little time the tendril will make a complete turn around the pencil. In half a minute you may see it getting ready for the coil, and in two minutes it may have finished the whole turn!

If you want to tease the tendril, you may do something a little different. Hold the pencil in place for about forty-five seconds, or until the tendril gets started for its coil. Then take the pencil away and watch the tendril straighten out again. In some plants you can keep this up time after time before the tendril will finally seem to get so tired that it will pay no attention to your pencil at all, and will never begin to coil. The thing has been done as many as twenty times in fifty-four hours.

How Tendrils Act as Anchors

Of course most tendrils never have to endure this sort of teasing. Their twig stays in its place, and they are soon coiled snugly around it. The tendril simply rotates around until it touches a twig, and then it is soon secure to the support. It may take two or three complete turns around the support, often tying a slipknot in addition. In the Virginia creeper the tip of the tendril, once it has found its support, develops a tiny vacuum-cup disk which enables it to hold on all the more tightly. And thus the vine goes on climbing.

When the tendril is first anchored to its support it forms a straight thread connecting the plant to the support. The tendril then begins to coil, half of the coil twining to the right and the other half to the left. This coiling draws the plant closer to its support, and the result looks just like a spring that has been coiled in opposite directions from its two ends. This gives an elasticity to the connection that makes it less likely to be broken in heavy winds.

And now that the tendril has completed its growth, it ceases to be irritable, and just holds fast. In the end many of the tendrils get so tough and woody that in some of the tropical vines we should need an axe to cut through them. In this state they make a powerful support.

Reading Unit No. 26

THE FLOWERS THAT HAVE NO PETALS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why many plants are called dicotyledons, 2–157
How dicotyledons are classified, 2–157
The flowers and seeds of the willow family, 2–158
Why walnut trees are valuable, 2–159
Beeches and oaks, 2–159-60
Birches and their uses, 2–160
Other plants without petals, 2–160

Things to Think About

What do all dicotyledons have in common?
What kind of flowers do the Apetalae have?
What evidence have we of sex in trees?
How is walnut wood used by man?
What is a "live oak"?
What well-known dicotyledons have no petals?

Picture Hunt

Where did the weeping willow tree come from? 2–157
Which sex bears the "pussy willows"? 2–158
Which sex bears catkins with stamens but no pistils? 2–159
Do elm-tree flowers bear petals? 2–160

Related Material

Why do plants have flowers? 2–101-4
What are the parts of a flower? 2–103
What goes on in lumber camps? 9–245-58
Who was King Arthur? 14–377

Leisure-time Activities

PROJECT NO. 1: To learn what is meant by seed leaves, open a lima bean and note the two equal halves, with the tiny embryo between, at the top. The halves are called cotyledons, 2–218.

PROJECT NO. 2: In April and May examine the catkins of such trees as poplar, birch, hazelnut, alder, willow, and oak, 2–158-60

Summary Statement

Not all flowers have petals. Plants bearing such flowers are classified as Apetalae. The flowers are found in catkins or singly. Many trees in this group have no stamens; since they have pistils they are females. Some trees have no pistils; such trees are males. Both sexes occur in the case of the willows and the hazelnut.

Photo by H. E. Zimmerman

Very many of our favorite trees have flowers without petals, often so small and inconspicuous that we scarcely notice them. The graceful weeping willow, which trails its slender branchlets as though drooping with sorrow, is only one among many of these old friends. The beautiful old tree in the picture was planted as long ago as the Revolutionary War. This kind of willow is a native of Asia; from there it was brought first to Europe and then to America, just as were many other plants which we prize.

The FLOWERS THAT HAVE NO PETALS

Nature Has Tried Many Ways of Making Flowers. Here Is the Story of Her Flowers without Petals

IN ANOTHER story we have told you that many seeds—those of grass and of pine trees, for instance—have a single seed leaf tucked away inside the seed. These plants are the monocotyledons (mŏn′ō-cŏt′ĭ-lē′dŭn). But there is another great group of plants whose seeds have two seed leaves. These plants are called "dicotyledons" (dī-kŏt′ĭ-lē′dŭn)—a name that means "having two seed leaves." All flowering plants belong to one or the other of these two great groups. Now the dicotyledons have certain very distinct traits, just as the monocotyledons have. For instance, besides seeds with two seed leaves, the mature plants usually have net-veined leaves and usually bear flowers that are divided into four, five, or six parts. When these plants are perennials their stems are woody. Since the dicotyledons are so numerous, they have been subdivided for convenience into three large groups—namely, flowers with no petals, flowers with many petals, and flowers with fused petals. This story is about the first of these great groups—the flowers without petals. The others you will find described in later chapters.

We usually think of flowering plants as having flowers which are conspicuous because of their large petals or because many flowers with small petals are clustered together. They are often made more showy by prominent colors that contrast with the

green foliage. But there are a number of flowers which do not have such conspicuous features; in fact, they are sometimes scarcely noticeable at all. Most of these are members of the group which we call the "Apetalae" (ȧ-pĕt'ȧ-lē), meaning that they have no petals. In some the sepals are lacking as well as the petals, and then the individual flowers appear very simple and incomplete.

It is interesting to find that many of our trees belong to this group, especially those of the Temperate Zone, the ones with which most of us are more familiar. These trees are interesting not only from a scientific point of view, but also from a commercial one. We shall be unable to go over all the plants of this group—there are over thirty families—so we shall have to be content with a general discussion of the more important ones.

There is one characteristic that binds all the plants of this group together, and that is the absence of petals in their flowers. Aside from this, we find the flowers varying a good deal, both in appearance and in arrangement. Some are arranged in clusters called catkins—an inflorescence (ĭn-flô-rĕs'-ĕns), or flowering, with the flowers borne closely along an elongated axis, like a stem—while others are produced singly. Some have both stamens and pistils, while others have only stamens or only pistils. A few rely on insect pollination, but mostly they rely on the wind and therefore have, as a rule, a pollen that is dry and powdery.

The willows and the poplars have long been grouped together in the willow family. While they differ widely in size and habit of growth, they are very much alike. Nearly all have rather scaly, furrowed bark; their branches are generally rather slender, growing in a drooping or erect position; their roots are tough and fibrous. The flowers are borne in furry catkins on separate male and female trees. All of us remember how these catkins will drop in large numbers from the tree on the path or sidewalk in the spring of the year. To some of us the catkins look very much like certain kinds of caterpillars, even though they are motionless. Always the flowers are simple, consisting for the most part of only stamens or pistils. The fruits contain seeds which are covered with silky hair, and when they are released they may float considerable distances in the air. Both willows and poplars are rapid growers and prefer damp soil. We find many willows growing along streams, sometimes with their roots entirely covered with water.

Photo by N. Y. Botanical Garden

We notice the catkins of the "pussy willow" much more when they are in bud than when they are in full bloom, for the bud of the male catkin is the downy thing we call a "pussy."

The pussy willow is familiar to us in March, when its furry catkins begin to expand. The basket willow, common along streams, has yellow twigs which bend over the stream. But all of the large willows in America are trees that have been imported. One, which we know as the crack willow, was brought from Europe for its fine basket-making qualities. Its twigs are very brittle at the point where they are attached to the trunk, and after windy days the ground underneath may be covered with them. To China we have

gone for the "weeping willow" with its long, slender, drooping branches.

After a forest has been burned or cut down, the poplars are often the first trees to spring up again. For that reason they are sometimes called "pioneer" trees. By their rapid growth they partly shade the slower-growing trees which need some protection at the start. In America the old settlers planted many poplars, and in traveling through the country we can still see many of them left. The aspen with its quaking leaf is a true poplar. The fragrant balsam trees, such as the balm of Gilead, are favorites for lawns or parks. Its "balsam" is a fragrant oil which oozes from various parts of the plant, especially from the shoots or buds.

The hickory nut in the topmost picture and the sprouting acorn in the center are both fruits of flowers that have no petals. The lowest picture shows male catkins of the hazelnut; none of the hazelnut flowers have petals, and the male catkin has no pistil just as the female catkin has no stamens.

Photos by Cornelia Clarke and American Museum of Natural History

Most of us have tramped through the woods in search of hickory, butternut, or walnut trees because we wanted their nuts. In the autumn and winter we can usually buy these nuts at stores. All of them come from trees of the same group. The fruits are the nuts we prize so highly for food, and they are inclosed in husks which may or may not split open. In the hickory we find the husks splitting in such a way that the nuts easily drop out, while in the butternut and walnut the husks turn brown and decay.

Why Walnut Trees Are Valuable

We prize the members of the walnut or hickory families not only for their fruits but also for their timber. The wood of the black walnut is especially valued for cabinetmaking, and is very beautiful in its natural finish. It is also widely used in the making of gun stocks, and for a time went into airplane propellers. While the hickory is not used for ornamental purposes, it is good for making handles and implements in which hard, tough, and strong wood is needed. Even though it is strong, it is also extremely supple.

Quite separate from the walnut family is another great group of plants forming the beech family. This family includes some of our largest forest trees of the Temperate Zone. The well-known oaks, chestnuts, and beeches make up a group with many similar characteristics. In all of them, we find the fruit to be a nut. The oak produces its nut or acorn in a cup which only partly covers the fruit. In the beeches and chestnuts the nuts are completely inclosed in burrs.

There are more than three hundred species of oak. Their life span is remarkably long. There are oaks in England that are known to be over a thousand years old. The Round Table of King Arthur's court was supposed to have been made from an old oak trunk eighteen feet in diameter. The arrangement and shape of the fibers give the oak wood its toughness and strength and durability. In olden times certain oaks were commonly used in the building of vessels. The large wood rays, which are especially prominent when the logs are quarter-sawed, make oak one of the most desirable of ornamental woods. Before the art of bending wood by artificial means was understood, the crooked trunks of some of the oaks were of especial

value where curved timbers were needed—especially in shipbuilding.

The oaks naturally fall into three main groups. Most of the trees shed their leaves, all at one time of the year, but there are certain ones, called the "live" oaks, which are evergreen. These hold each crop of leaves for more than a year, so that there are always green leaves on the trees. The other groups differ in leaf, fruit, and wood. In one group, called the "white" oaks, the leaves have rounded lobes and the fruit matures in one growing season, while in the other group, called the "black" oaks, the leaves have pointed lobes and two growing seasons are necessary for maturing the acorns. These characteristics clearly separate the groups.

Ever since early times much has been said of the beech tree in song and story. The Greeks considered it a symbol of prosperity. The beeches give a stateliness to the woods in which they grow. The nuts are sweet and have a fine flavor; many of the wood creatures relish them. Beechnuts have also been used in Europe as food for man. Some of the beeches have long been used in park plantings, especially the beautiful one with russet leaves called the copper beech. The wood is close-grained, hard, and heavy, and has many uses.

The birch represents a family to which such plants as alders, hornbeams, and hazelnuts also belong. The family is widespread, with some of its members living in the extreme north. The simple leaves of the birches are thin and dainty, swaying gracefully in the slightest breeze. Both the male and the female flowers are borne in catkins on the same tree. The seed in most cases is flat and winged.

The birch remains the most important member of this family, for it has so many uses. In America the Indians made constant use of it. They made baskets and buckets and boxes of its bark. They stretched the bark over framework in fashioning their canoes, and hewed its wood for paddles. Strips of bark, rolled tightly, served them as torches. Some of their lodges were covered with sheets of bark. They even used it as paper for the little writing that they did.

And birch still has its uses. In all the larger birches, the wood is fine of grain and useful in cabinetmaking. Birch oil, having a wintergreen flavor, is a colorless liquid obtained from the inner bark of the cherry or sweet birch. It is widely used as a flavoring for soft drinks, candies, and other articles of trade.

There is yet one group of the "Apetalae" of which we must make mention. It offers a great contrast to those we have already discussed, for most of its members are herbs and many of them are inhabitants of the Tropics. They are sometimes called the "Centrospermae" (sĕn′trō-spûr′mē), for the embryo is in the center of the seed. Their flowers are usually perfect—containing both stamens and pistils—and are not arranged in catkins. Some of them are weeds, while others are some of our most useful food and ornamental plants. We are all familiar with rhubarb, sugar beet, buckwheat, and spinach as food plants; and with garden flowers such as cockcomb, foxtail, and four-o'clock.

Among the groups we have not discussed are occasional plants with which many of us are acquainted. Such plants as the fig, mulberry, elm, bayberry, rubber plant, and nettle are known to everyone. Some of these yield well-known products; and the mulberry supplies the leaves that the silkworm feeds upon.

This graceful spray shows the leaves and a cluster of flowers of the white, or American, elm. It is one of our commonest trees, known to nearly everyone. Yet how many of us could have recognized these little apetalous flowers if we had seen them without the leaves?

BOTANY

Reading Unit No. 27

FLOWERS THAT HAVE MANY PETALS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why plants have colored petals, 2–163

The importance of flower shapes to a plant, 2–164

The pink family, 2–164-65

How pollen thieves are foiled by flowers, 2 165

The large rose family, 2–165-66

How pea flowers invite bees, 2–166

How members of the pea family enrich our soil, 2–168

The carrot family, 2–168

Things to Think About

How do flowers manage to exchange pollen with others of their kind?

Why do some flowers open only at night?

What different plants belong to the rose family?

Why do imported pea flowers sometimes fail to produce seed?

How may legumes get more nitrogen than is in the soil?

Picture Hunt

Why do cultivated roses have a great many petals? 2–163

In what respects are members of the rose family alike? 2–162

What cactus fruit do we eat? 2–167

Why has the "spineless" cactus disappointed cattle raisers? 2–167

Related Material

How do blackberry and raspberry bushes remind one of rose bushes? 9–158

What are the names of the different parts of a pea flower? 2–103

Leisure-time Activities

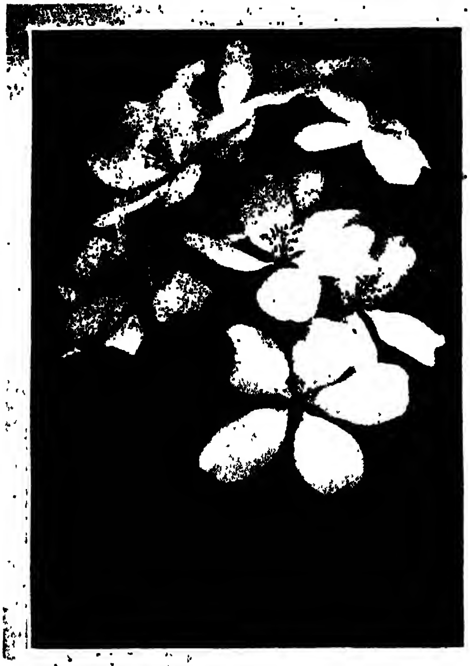
PROJECT NO. 1: Make an artificial rose, 14–54.

PROJECT NO. 2: Pull up clover or some other legume by the roots. The little wartlike masses contain the bacteria that extract nitrogen from the air and give it to the plant, 2–168.

PROJECT NO. 3: Observe a sweet-pea flower being visited by a bee. How does the insect enter and leave? What does the bee carry away?

Summary Statement

Flowers with many petals are borne on most of the plants. The showy flowers are designed by color and shape to attract certain insects. This is done to cause an exchange of pollen between members of the same species, so that seeds may form.



Photos by Cornelia Clarke

On this page are four of the blossoms we know best. The two pictures above show apple blossoms. At the left is a cluster of them from a cultivated apple tree; we are to imagine the petals flushed with delicate pink. At the right is the wild crab apple, which is the ancestor of our cultivated trees.

Photos by Cornelia Clarke

At the left are cherry blossoms, and at the right blackberry blossoms. All the plants on this page belong to the great family of Rosaceae, or the rose family; the blackberry is closest to the rose.

FLOWERS THAT HAVE MANY PETALS

They Are One of Nature's Experiments in Blossoms, and They Give Us Some of Our Most Gorgeous Flowers

EVERYONE with eyes to see is delighted by a beautiful flower, but it was not to please mankind that plants developed their bright blossoms. Plants with gay, showy flowers attract many insect visitors that carry their pollen. Mostly the insects come by day, but sometimes in the dead of night. The plant world largely depends upon the attraction a flower can offer to the insect pollen carriers, and most of the insects carry pollen from flower to flower after learning to associate the colored flowers with the presence of nectar or other food. But there are many other things in flowers which are also important in attracting insects to come and carry the pollen.

There are only six main colors, or seven if we may add white. These seven colors may combine in many shades and tints, but even all of these variations alone cannot account for the fact that different kinds of insects sometimes visit their own particular kind of flower and no other.

Some flowers have developed so that they are attractive to a single kind of insect visitor and will keep out others. For pollen thieves are very common among the insects. They steal the nectar, and they eat the pollen instead of carrying it; and sometimes they come before the pollen is ready to be carried at all. So there is a constant game, or contest, between the flowers and the insects; they both need each other but must not impose on each other. At the end of the contest both gain; the pollen *does* get carried and the insect

Photo by Cornelia Clarke

Of all the countless kinds of many-petaled flowers, none are more general favorites than the roses. Who, for instance, would not like to have a bush or a bouquet of Paul Meyer roses, such as these? Elaborate flowers like this do not grow wild; wild roses have but few petals in comparison. What has happened is that some of the many stamens of the wild rose have turned to petals—have "reverted," as botanists say. The men who cultivate roses have, by careful selection, fostered this tendency to "double."

does get what it came for—usually nectar, which it will make into honey.

It has often been observed that color, by itself, is not absolutely certain to attract the right insects. Sometimes it attracts many thieves. The shapes of the flowers, as well as their odors, make a great difference in the number and kind of insect visitors that they will attract.

The forms or patterns of flowers, then, are about as important as their color. Although there are certainly a great many different shapes in flowers, we can divide all of them for the moment into two great groups or classes. The first of these always has separate petals in the flowers, as is the case in a rose or buttercup, while the other always has united petals, making the flower somewhat bell-shaped or funnel-shaped, as is the case in the bell-flower or the morning-glory.

Photo by Cornelia Clarke

One of the most-loved of our common wild flowers is the buttercup, which scatters our spring and early summer fields with gold. You will notice that, like the uncultivated rose, the buttercup has five petals and a great many stamens.

This story has to do only with the flowers which have separate petals; they seem to be the first kinds of flowers that developed any petals at all. There are thousands of different kinds of plants with flowers of separate petals—so many that the botanists have given them a group name, the "Polypetalae" (pŏl'ĭ-pĕt'ȧ-lē). That word is Greek for "many petals."

Flowers with Separate Petals

The Polypetalae, then, are a great group of plants, most of them with net-veined leaves and with flowers having separate petals, no matter what the shape of the individual flower may be. The group is so large that we cannot mention all its members in detail. But it is so important in the general plan of the plant world that we must learn at least what it is like. In so doing, we shall find that many of our favorite wild flowers and garden flowers belong to it.

There are more than a hundred and seventy families of plants in the Polypetalae. Let us look at just four of the most familiar ones. They will show us four different kinds of development. For all through this great group of plants with separate petals, there seems to go on this game between insect visitors and flowers, each appearing to profit by the arrangement.

In the Polypetalae there are a number of flower conditions to be found. In some of the plants, for instance, we find nothing but colored sepals, such as we may see in the hepatica; these sepals only look like petals. But in the pink family perfectly regular flowers have been developed with both sepals and petals, and in such profusion that there are over 1,300 different kinds of plants in the family. All of them have opposite leaves and swollen joints, as you can see very clearly in the carnation of the florists' shops. And all of them have dry fruits, so that they produce none of the well-known edible fruits or vegetables. They are known mostly for their large number of pretty garden flowers, which have been cultivated from very early days. Chief among these are the pink, the carnation, and sweet William.

These three plants came from the temperate regions of Europe and Asia and have now gone all over the world. Each of them has a peculiar "claw," or base, to each petal, which makes it difficult for most insects to get down to the nectar at the bottom of the flower. But insects with the proper sort of mouth parts can get all the nectar they need,

Photos by Cornelia Clarke

At the right above is the lovely wild rose with flowers wide open. On the left there are two buds not yet opened and an old flower that has bloomed and dropped its petals. Its many stamens show plainly; and it is clear how many of them there are to revert to petals when the flower doubles.

and so carry the pollen of the pink and sweet William all through the summer.

Carnations, however, as we know them, are double flowers. Instead of having four or five petals, as do most members in the pink family, they have a great many petals so thickly clustered that the stamens and pistils are buried in them. As in many other double flowers cultivated by the florist, the stamens and pistils are so hidden as to be useless. The carnation, perhaps the most widely cultivated plant in the pink family, must therefore be grown mostly from cuttings and not from seed.

Insect Thieves That Steal Pollen

Pollen stealers must have been very common in the early history of the pink family, for various methods seem to have developed which prevent them from stealing. Some of the thieves could crawl into the center of a flower, get some honey, and sneak out, without even touching the pollen. Perhaps one of the best methods of preventing such a a practice is found in the catchfly. It looks very much like a pink, and is so arranged that helpful insects are invited, but useless thieves are kept out. If you examine the stem and calyx of the catchfly, you will find that both are covered with a sticky gum. This acts just like fly paper, and keeps all but the proper insect visitors away from the catchfly.

Why Certain Flowers Open at Night

Other thieves are kept away because the flowers of some plants in this family open only at night, when their particular night-flying visitor is likely to come. Others let loose their sweet odors only when certain night-flying moths will be attracted to them. All the family have insect pollen carriers, even such humble members as the chickweed, stitchwort, and many others.

In the pink family there are no shrubs or trees, or plants with fleshy fruits. But all these are found in the rose family. The rose family is so large as to contain over two thousand different kinds of plants, all of which have alternate leaves and no conspicuously swollen joints. Hundreds of the family are little known except to experts, but many others are familiar to us all. In addition to the rose itself, the family contains many other common plants. It comprises such wild flowers as the cinquefoil,

burnet, avens, queen of the prairie, and the agrimony; such garden shrubs as the spiraea, the nine-bark, and the kerria; such fine fruit bushes as the blackberry, raspberry, logan-berry, and the strawberry; and such fine orchard trees as the pear, apple, plum, peach, cherry, quince, apricot, and almond.

A Family Known the World Over

So the rose family is very important to us. Comprising herbs, shrubs, and trees, many of them tropical, the family is world-wide in its distribution. All but one of its members have their pollen carried by insects, very often by bees, as in the apple blossom. Of course they all have separate petals, and the flowers are always perfectly regular—which, as we shall see presently, is not true in all families in the Polypetalae.

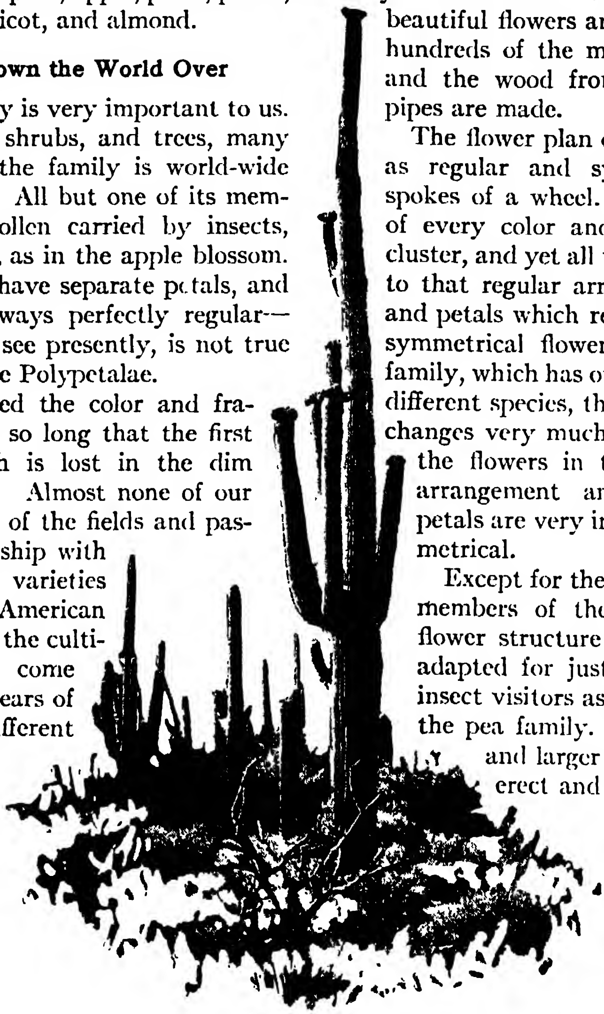


Photo by N. Y. Botanical Garden

Nature sometimes plays strange tricks when she is making flowers. Here is a giant cactus in flower, with its queer flower-bonnets lifted high above the desert.

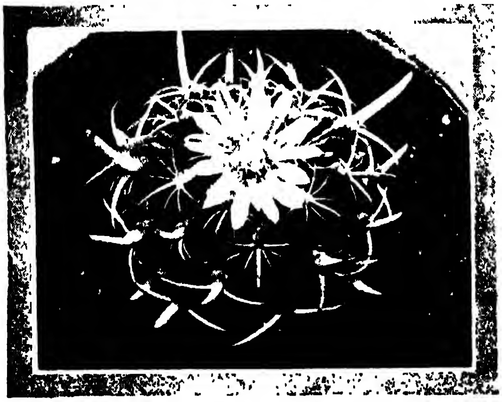
People have loved the color and fragrance of roses for so long that the first cultivated rosebush is lost in the dim shades of the past. Almost none of our common wild roses of the fields and pastures have any kinship with any of the garden varieties of rose, such as the American Beauty. Nearly all the cultivated roses have come from hundreds of years of experiment with different plants, most of which are Asiatic. To the cultivated roses we have given names like the American Beauty, Meteor, Los Angeles, Admiral Ward, Crimson Rambler, and hundreds of others. Nearly all of these have nearly useless stamens and pistils, and consequently are not grown from seed. French, English, and American rose breeders have produced most of the gorgeous colors and scents of our cultivated roses, after an enormous amount of work and years of very careful selection.

Similar care and selection have gone into developing the cultivated fruits of the rose family, of which there are thousands of varieties. How some of these have been produced we shall see in our story of the common fruits. The chief thing of practical importance to most of us about the rose family is that from it we get scores of beautiful flowers and flowering shrubs, hundreds of the most delicious fruits, and the wood from which briar-root pipes are made.

The flower plan of the rose family is as regular and symmetrical as the spokes of a wheel. There are flowers of every color and of every kind of cluster, and yet all the rose family stick to that regular arrangement of sepals and petals which results in a perfectly symmetrical flower. But in the pea family, which has over twelve thousand different species, the plan of the flower changes very much. For in nearly all the flowers in the pea family the arrangement and shapes of the petals are very irregular and unsymmetrical.

Except for the orchids and for the members of the daisy family, no flower structure seems so perfectly adapted for just the right kind of insect visitors as do these flowers of the pea family. There is an upper and larger petal, which stands erect and is sometimes called the "standard." Then there are two side petals, called the "wings," and two lower petals, often somewhat joined together, that are usually called the "keel." The whole highly-irregular flower is not unlike a butterfly in shape, and within it are concealed the stamens and pistils. Bees seem to be the only insects that can reach the pollen in many plants of the pea family, and some of the plants that have been taken into foreign countries have failed to produce seed just because the right kinds of bees were not there to carry the pollen.

On this page are flowers and fruit from various kinds of cacti, those strange desert plants that are native only to tropical and subtropical America. Above are two cacti in flower. The one at the left is growing at Big Springs, Texas, and the one at the right somewhere in Mexico. Cactus flowers are very often large and showy, as we may judge from these pictures, and their coloring is often brilliantly beautiful.



In the picture at the left above we are looking down upon a Mexican cactus in full bloom. The beauty of a cactus flower consists not only in its size and color but in the many conspicuous stamens at its center, as this picture shows very well. The ovary at the base of the flower develops into a fleshy fruit. In many kinds of cactus this fruit is edible. At the right above is a pile of such cactus fruits. They are much the best-known sort; they come from Opuntia, and are nicknamed prickly pear or Indian fig.

The cactus at the left above is sometimes called the "spineless" variety. The priests in the Mexican missions knew about this kind long ago, and hoped they had found a new food for cattle. The trouble is that even the "spineless" cactus is not constant in its spinelessness, and efforts to make it so have so far failed. At the right is the flower of another cactus—which never even pretended to be spineless.

Besides the garden pea, the bean, and the lentil, there are many plants in the pea family which have highly nutritious seeds and fruits which are rich in protein. All the seeds are borne in a pod of some sort, usually not unlike that of the common garden pea. Such fruits are called "legumes" (lĕg'ūm), and are found in no other family of plants. For this reason the plants of this family are often called legumes. Sometimes the legume will be very long and woody, as in the honey locust tree; one tropical tree of this family has a woody pod over two feet long.

Not only does the pea family have butterfly-shaped flowers and bear legumes that yield us rich foods, but some of its tropical members are very valuable in other ways. For these tropical trees give us some of the finest timbers in the world, such as the logwood, the Brazilwood, the acapu, and the angelim. Also from the Tropics comes the beautiful acacia.

It has been known for a long time that certain special kinds of bacteria (băk-tē'rĭ-ȧ), or microscopic plants, make their homes in the roots of many of the members of the pea family, and that these bacteria are able to take the free nitrogen gas from the air and combine it with other elements, making a form of nitrogen which green plants can use. No green plant can use free, or uncombined, nitrogen, even though the air all about is more than three-fourths nitrogen gas. For this reason plants of this family, such as peas, vetch, beans, and clover, if they have the proper bacteria in their roots, can grow in soils without combined nitrogen where other plants cannot grow. This is one of the reasons why plants of the pea family have been cultivated for centuries as valuable crops to enrich the soil with nitrogen as well as to supply an abundance of protein food.

The Polypetalae have their flowers arranged in many different kinds of clusters; but in the parsley family, or carrot family, as some people call it, an unusual arrangement has developed. For in the parsley and carrot, and in all the other 2,700 different species in this large family, the flowers are arranged in an "umbel." The term comes from a Latin word meaning a little "shade" or "umbrella"; and the ribs of an umbrella, because they are all fastened at one place, are very like the tiny stalks of an "umbel." In this kind of flower cluster all the stalks of each flower arise at one point, and the tiny flowers at the ends of the stalks are often arranged in flat-topped or roundish clusters not unlike a small umbrella. Sometimes there are many umbels, all arranged in one big umbel, as you may see them in the common parsnip or in Queen Anne's lace. Such clusters are called "compound umbels."

Some of the plants of this family have food for us. But others are deadly poisonous. The poison hemlock, which killed Socrates, and several related North American weeds, all have a bitter, very poisonous juice. The seeds of some members of the family are strong and pleasant to smell, and are used for seasoning; among these are our caraway, coriander, dill, anise, and the celery seed from which celery salt is made. But the plants we know best in this family are the carrot, parsley, parsnip, and celery, all of which have been cultivated for many centuries.

The whole of this large family, like most of the Polypetalae, have insect visitors to carry their pollen. But each flower is so tiny that only the smallest kinds of flies can be of any use to them. One of the flowers of Queen Anne's lace—or queen's needlework, as it is often called—is so small that a fly only one twenty-seventh of an inch in length is its chief insect visitor. Yet the whole cluster may be two inches across; while in some tropical kinds the compound umbel may be over two feet wide.

To mention only these four families of the Polypetalae can give little idea of their importance in Nature's plan for flower structure and arrangement. Some of the others are just as important as the pinks, roses, peas, and parsley. And many of the other families we know even better than we know these four. Some of the other families in the Polypetalae, with the number of species in each, are: buttercup (700), mustard (1,900), cactus (1,800), laurel (1,000), geranium (600), spurge (4,000), and the mallow family (700).

BOTANY

Reading Unit No. 28

FLOWERS WITH PETALS JOINED IN ONE

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Things to Think About

How are stamens and pistils protected in some flowers?

How does a flower of the heath family make sure that a bee gets its pollen?

What members of the heath family do we eat?

What gives the pennyroyal and other mints their odor?

Why are daisies and black-eyed Susans classified as "Compositae"?

Picture Hunt

Related Material

Leisure-time Activities

PROJECT NO. 1: Using a lens, pick a daisy head apart and see how many flowers are crowded together. Is the daisy head one flower? 2–175

PROJECT NO. 2: Hunt for mint on a hillside or in a meadow. Crush the plant and smell it. Feed some catnip to a cat, 2–175.

Summary Statement

Tubular flowers are the result of the joining together of petals. The tubes protect the stamens and pistils and force insects to get inside, where they pick up the pollen. Some flowers in this group have hair-trigger stamens which at the slightest touch hit the insect and dust it with pollen. Morning-glories, blueberries, milkweed, daisies, marigolds, and chrysanthemums have such flowers. Daisies have many flowers crowded into a single head, for economy and efficiency.

FLOWERS WITH PETALS JOINED IN ONE

The round yellow or orange balls of the cultivated marigold, such as these, have been developed by gardeners by "doubling" the wild flower.

This common mint makes it possible for us to see the irregular flowers very well. It is called bee balm but butterflies too seem to like it!

Photos by Cornelia Clarke

Doubled asters like these brighten many a garden in autumn, just as their wild sisters brighten the roadsides and fields.

These chrysanthemums—like yarrow, goldenrod, tansy, marigold, asters, thistles, and daisies—belong to the group of complicated Composites.

Photo by Cornelia Clarke

Was ever a flower more happily named than the wild morning-glory? For it is truly a glory of the morning, since it opens its delicate pink or white cups to the morning sunshine and then droops and closes them as if to sleep. This is one of the most familiar of the flowers with petals joined in one.

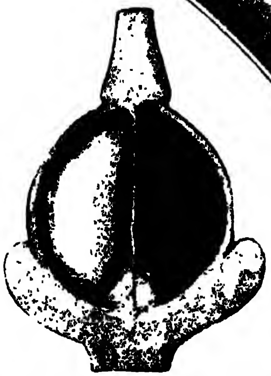
FLOWERS *with* PETALS JOINED *in* ONE

These Are One More Experiment of Nature in Her Great Work of Making Blossoms. Among Them Are Some of Her Loveliest Cups and Bells

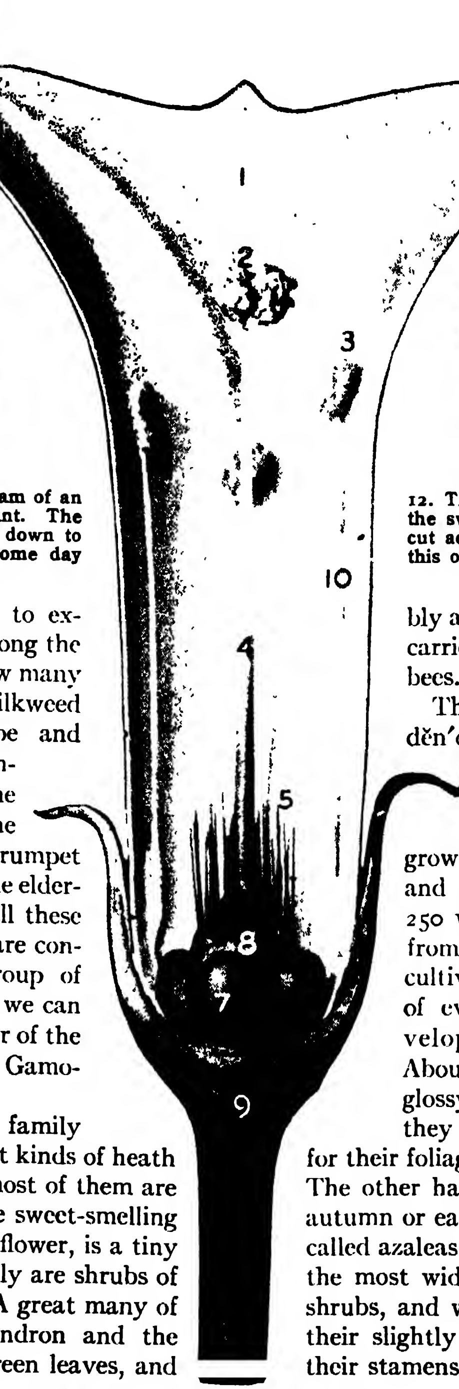
IN SEVERAL stories in this book we have seen that there are some flowering plants with very simple flowers without any petals, and others with very beautiful and rather complex flowers like the pinks and roses. But the history of flowers would not be complete if we ended it with the ones like the rose and pink. These flowers have all their petals separate. There is still another type in which all the petals are joined together.

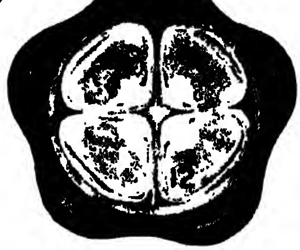
Flowers with their petals joined into some sort of tube or bell-shaped or funnel-shaped corolla may have advantages over flowers with separate petals. There is greater protection for the essential organs of the flower if they are surrounded by a united corolla. The stamens and pistils of a bellflower or a morning-glory, for instance, are far better protected than those that are left naked by the falling of the separate petals of an apple blossom. Whatever the shape and color of a flower, this protection of their essential organs is important.

Flowers with united petals are much more common than we may imagine. Though they probably have been the last to develop, they have thriven so well that there are over fifty large families of plants, with thousands of species, that have this type of flower. All of these are grouped by the botanist in one large class called the "Gamopetalae" (găm′ō-pĕt′ȧ-lē). "Gamo" is from a Greek word meaning "marriage," and "petalae" is simply plural for "petal." So the word really means "married petals," and that description comes very near being the truth about these flowers. If you will look at any gamopetalous flower, such as the morning-glory, you can easily see the joints between the separate petals that have been united to make up the corolla. Often you can tear the corolla apart along the joint, or "sinus" (sī′nŭs), as it is called. And you will find a few flowers among the Gamopetalae in which the petals are not entirely united. But most of the Gamopetalae have a completely united corolla.



11. **This is an enlarged diagram of an ovary of the sweet-potato plant. The ovary has been split up and down to show an ovule, which will some day ripen into a seed.**





12. **This diagram shows an ovary of the sweet-potato plant with the ovary cut across. There are four ovules in this ovary; if they all ripen there will be four seeds.**

It would be pleasant to examine all the flowers among the Gamopetalae and see how many you could recognize. Milkweed and phlox, Indian pipe and sweet pepper bush, primroses and gentians, the olive and the ebony, the borage and tomato, the trumpet creeper and cucumber, the elderberry and buttonball—all these and hundreds of others are contained in this great group of plants. About the most we can do here is to see what four of the leading families of the Gamopetalae are like.

Let us take the heath family first. Over 1,200 different kinds of heath plants are known, and most of them are shrubby ones. Even the sweet-smelling trailing arbutus, or Mayflower, is a tiny shrub. Most of the family are shrubs of the temperate regions. A great many of them, like the rhododendron and the wintergreen, have evergreen leaves, and a good many grow in bogs or on heaths, from which fact they get their family name. Probably all of them have their pollen carried by insects, mostly by bees.

The rhododendron (rō′dō̂-dĕn′drŏn) that we know so well in gardens is one of a group of magnificent flowering shrubs which grow mostly in Eastern Asia and in North America. Over 250 wild kinds are known, but from them hundreds of different cultivated shrubs with flowers of every color have been developed by the gardeners. About half of the shrubs have glossy evergreen leaves, and they are therefore much planted for their foliage as well as for their color. The other half drop their leaves in the autumn or early winter, and are usually called azaleas. Both of these are among the most widely-planted of ornamental shrubs, and we can easily tell them by their slightly irregular corollas and by their stamens and styles. These always bend upward so as to touch the under side of a visiting bee, which brushes off their pollen

This is a model of the flower of the sweet-potato plant. The petals and sepals of one side have been taken off to show the construction of the flower within. The corolla tube (1) is formed of fused petals. The stigma (2), the style (4), and the ovary (8) are all parts of the pistil. The parts of the stamen are the anther (3) and the filament (10). At 6 you see the sepals of the calyx, at 9 the flower stalk; 5 and 7 are hairs and a fleshy disk attached to the ovary—they are unusual structures.

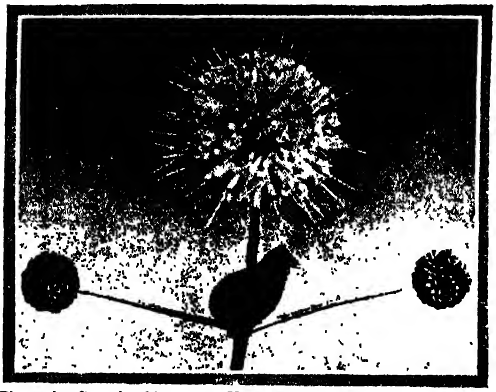
This is a spike of mint. Though it is hard to see in a picture, the stem is not round but angular. The flowers are irregular and lipped.

The yarrow has a strong odor, but it is not a mint. It is a rather coarse plant belonging to the aster group, and grows as a weed in many fields.

Photos by Cornelia Clarke

This is only one of the many varieties of goldenrod, a wild autumn flower related to the asters.

The tansy, also related to the asters, has a strong aromatic odor and a bitter taste. It is sometimes used in making a medicinal tonic.



Photos by Cornelia Clarke and H. E. Zimmerman

At the left above is a sprig of buttonbush, one of the Gamopetalae but belonging to a group that we have not had time to describe. It is one of the many flowers with petals fused into a cup, and is related to the honeysuckle and the elder. At the right is a flower cluster of the common thistle.

at the same time that he is painting their stigma with the pollen from another flower.

The heath family is thus famous for the beautiful flowers of the azalea and the rhododendron, of the heather and the mountain laurel. It also gives us such delicious fruits as the blueberry, huckleberry, cranberry, and bilberry. Most of these have tiny bell-shaped flowers usually found hanging upside down, in various kinds of clusters. Some of the fruits have a peculiar bluish "bloom," as is the case with most of the blueberries, but the huckleberry is usually quite black and is not so good to eat.

Unless you are a farmer and obliged to think of it as a weed, you may very well prefer the field daisy to any of its cultivated relatives. This starry flower must have been delighting men for many generations, for long ago the English-speaking people named it "day's eye"—the eye of day—which we have come to shorten to daisy. The Germans call it "meadow pearl," and the French "marguerite," which means "pearl," also.

Next there is the morning-glory family. Everybody knows the beautifully-colored, funnel-shaped flower of the common morning-glory. We know it so well that if it were the only plant in the family there would be no need to say much more about it. But it happens to be only one of more than a thousand different kinds in the same family, all of which have perfectly regular flowers and most of which are vines.

When the Spaniards came to the New World they heard the Indians talking about "batatas," a rich food. This was the starchy root of a creeping morning-glory, and from that plant has come our modern sweet potato. That vegetable rarely flowers in the United States, but in its tropical American home it has rose-violet flowers much like those of our common morning-glory. Through a mistake of the Spaniards, the word "batatas" was later applied also to the common potato, and in fact the very word "potato" came from the Indian "batatas." Ever since, and because of this mistake, we have had to use the name "sweet" potato for this morning-glory with the big edible root.

Much farther north, near New York, there grows another wild morning-glory with a root twenty times the size of a sweet potato. It is the manroot. Its root is not quite so big as a man, but will sometimes weigh a hundred pounds. It used to furnish the Indians with a coarse starchy food, as did also a few other morning-glories

with large edible roots. Some of the other kinds, such as the jalap (jăl′ăp), yield medicines, and still others are quite poisonous.

Then there is the mint family. In this family the flowers are very irregular, and there are strong-smelling oils all through the tissues of the plants. The morning-glories and many related families all have perfectly regular, symmetrical flowers, but all the 3,400 different members of the mint family have very irregular ones.

Plants with a Pungent Odor

While the irregular, two-lipped flowers of the mint family have no very strong odor, the foliage of nearly all of them has a pungent smell which it will hold for a long time. Lavender and thyme (tīm) leaves will still keep the peculiar lingering smell of the plants even after they have lain inside a book for many years. So will the leaves of basil, pennyroyal, mint, catnip, marjoram (mär′-jô-răm), and many others of the mint family.

Although most of the plants in this family have strong-smelling foliage, the mere odor is not a safe guide in trying to identify a plant of the mint family. Usually the plants will have the combination of a two-lipped flower, a square stem, and opposite leaves.

Why Cats Like Catnip

Why cats are so fond of catnip no one really knows. Even the early Greeks and Romans knew that some particular odor in its oil gave such a pleasant sensation to a cat they they called the plant "cataria." And we know that wild lions and tigers, who come from regions where catnip does not grow, are just as frolicsome as ordinary cats when a sprig of this plant is put in their cages.

Finally, there is the daisy or sunflower family. When you pick a daisy to pieces and say over the old jingle of "Rich man, poor man, beggarman, thief," you are not tearing off a petal at a time. You are really tearing off a whole flower, scores of which are crowded into the one head which we call a daisy. For the daisy, dahlia, aster, boneset, chrysanthemum, zinnia, and over 13,000 other members of this largest of plant families, all have their flowers arranged in a "head." Most of them may not look so much like a head as do the huge chrysanthemum and dahlia, but all the family have their flowers tightly packed in this peculiar cluster known as a head. Because of this arrangement the family is often known as the "Compositae" (kŏm-pŏz′ĭ-tē), which is a term applying to plants with flower heads composed of many separate flowers.

Besides the plants already mentioned, the Compositae comprise such common plants as the goldenrod, yarrow, camomile, tickseed, fleabane, coltsfoot, lettuce, chicory, and, in the Tropics, a few shrubs and trees. The family is scattered all over the world, and in many ways it is the most complex and difficult to understand. All these flowers are pollinated by insects, and certainly this arrangement has its advantages.

Flowers like the Common Daisy

If we take the common daisy as an example it is easier to understand just what a head in the Compositae really is. We can easily see that there is a series of white flowers, which most people call petals, around the edge of the head. But in the center of the head is another series of yellow flowers, tiny and tubular, such as make up the cone-shaped center of a black-eyed Susan. The outer white flowers are called the "ray" flowers and the inner ones the "disk" or "tubular" flowers.

Both tubular and ray flowers have stamens and pistils, of course very tiny and hard to see. But insects notice them, probably attracted by the showy ray flowers. This cannot always be true, however, for some of the Compositae have no ray flowers at all. In fact, the family is divided into three groups, just on the basis of this matter of tubular and ray flowers. The first group has only ray flowers, as in the chicory, lettuce, and dandelion; and these plants usually have a milky juice. The second has only tubular flowers, as in the boneset, cat's-foot, some of the everlastings, and the thistle. But the third group has both ray and tubular flowers. This is the largest group of the Compositae. It contains the aster, dahlia, chrysanthemum, goldenrod, sunflower, and thousands of others.

BOTANY

Reading Unit No. 29

WHEN A PLANT IS CALLED A GRASS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How man and beast depend upon grasses for food, 2–177
Where grasses can grow, 2–178
Characteristics of grasses, 2–178-79
The fruit of grasses, 2–179
Bamboos, 2–179

Things to Think About

Why have wars been fought over grasses?
How may grasses affect people who are victims of hay fever?
What is a "grain"?
What is the tallest grass in the world?
What uses have grasses, besides serving as food?

Picture Hunt

What do cattle eat in winter? 2–177
What grass has its flowers in a dense spike? 2–178
What enables bamboos to stand up? 2–179
What grass furnishes a most important food for man? 2 180
How does wheat grow? Color plate, 9 96

Related Material

How is corn used? 9–104-6
How is wheat raised? 9–101
Why is wheat a valuable food? 9–102
How is rice cultivated? 9–108-11
What are cereals? 9–118-20

Leisure-time Activities

PROJECT NO. 1: Make a collection of grasses. Dry them between blotters in a plant press, and have them identified at your local museum or by a botanist.

Summary Statement

Without grasses man would probably be as backward as the ancient cave man. Grasses feed him and his domesticated animals. Among the grasses are hay plants—like timothy—orchard grass, and important cereals such as rice, wheat, barley, rye, and corn. The tallest is the bamboo, which is important in the Orient; it also has the swiftest growth. Grasses have hollow stems, sheathing leaves, and inconspicuous, wind-pollinated flowers that lack petals.

Photo by International Harvester Co.

Grasses are about the most useful of plants so far as man is concerned. Some of them, like wheat or corn, yield fruits we use for food. Some of them our cattle graze on when the plants are growing. The grasses of one whole group, including common grass and timothy, we gather entire—stems, flowers, and fruit- and stack away in our barns. The man above is using the machine to bale hay mechanically.

WHEN *a* PLANT IS CALLED *a* GRASS

Here Is the Story of the Vast Number of Growing Things That Have That Name; and as You Will See, They Are Very Interesting and Useful

OF ALL the plants covering our hills and valleys, grasses are among the most common and to man the most important. We attach a great and deserved importance to their uses, and we seldom fail in praise of their beauty. Yet even so, we little realize what a beneficial and lordly group of plants we are praising.

Many ancient wars were fought over grasses and grass products. The Chinese and Japanese waged war over rice; the Europeans fought over wheat; and the Indians in America struggled for corn—all of them true grasses. Even less important grasses have been the subject of age-long controversies; these were mostly pasture grasses upon which certain groups depended for the very life of their cattle and themselves.

But those wars need never be fought again, for we now have steamships and other means of transportation to carry grass products to any part of the world that may be in need of them. And it is fortunate that this is true, for to-day the world's need for these plants is much greater than when the Aztecs of Mexico fought over an especially fertile bit of corn land. The direct products of the grasses—mostly cereals—serve as the chief source of food for man. But our dependence on them does not end there. All the beef, lamb, and much of the pork we eat depend upon the pasture grasses or upon grains. Most of our chicken feed comes from grains. And there are many other uses to which grasses have been put. Before we learn what these are, let us look carefully at

the grass family, how and when it grows, and what it really is.

Grasses are the most abundant and the most universally distributed of all flowering plants. They flourish in every part of the globe where vegetation can exist. They grow in every kind of soil, in company and alone, often covering large areas with a single species. Certain grasses are abundant in prairie regions where the rainfall is too scant for forests. Others grow in swamps, partly submerged in water. Some grow in the poorest of waste land where little else can live, while others grow in the richest prairie soils. Some grow on high mountains, fringing rocky ledges and steep crags. There seems to be no species which grows in the ocean, although some do grow in salt water.

The cooler parts of the Temperate Zones are characterized by dwarf, usually slender grasses with short leaves. The frozen tundra of the Arctic, when thawed during the short summer, exposes a growth of stunted grass mixed with lichens and mosses. The flowering plant farthest south in the Antarctic is a grass. In the Tropics grassy areas give way to forests. But wherever there is a tract of open country, the favorable temperature and moisture conditions allow for a luxurious growth of tall, herbaceous grasses.

Photos by U. S. Department of Agriculture

Here are the flower and fruit stalks, or "heads," of two very important grasses. At the left is a spike of ripened barley. It has formed from flowers not unlike those of the timothy grass shown in blossom at the right.

All the grasses except the bamboo and a few relatives are true herbs—they do not have woody stems. And all but a few of the important grasses, including corn and sugar cane, have round hollow stems. It is only at the joints of the stem that there is found a solid partition.

Grass leaves, as everyone knows, are mostly long, slender, and tapering, but some of the tropical grasses have broad leaves unlike any to be seen in the temperate regions. Nearly all the common kinds die down to the ground every year, but have stout underground stems and roots which carry them easily over the most bitter winter; and all the turf and pasture grasses have creeping rootstocks which bind the little plants together into a close mat.

The stems of the herbaceous grasses are stiffened in an interesting way. When they start growth in the spring, the stems and leaves are soft and juicy, excellent for pasturage. As the stems get older, they begin to absorb silica (sĭl′ĭ-kȧ) from the soil. This, one of the hardest of minerals, is deposited in the outer layers of the stems.

THE GRASSES

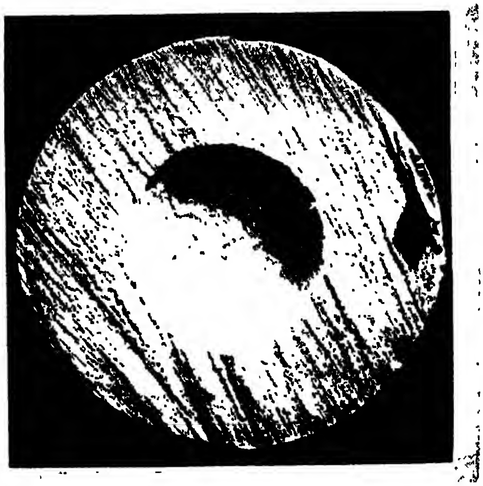
Most of the grasses have very tiny flowers, entirely without petals. They are crowded between tiny scales, which are pressed into small spikes. It is these spikes, often gathered into clusters, that we see waving over a field of corn or wheat. Many of the scales are empty, but those that do contain flowers finally open enough for us to be able to see the stamens and pistils. The stigmas of the pistils are usually fringed.

Grass pollen is very plentiful, and it is sometimes said that bees steal it. But grasses are generally dependent upon the wind for pollination. Some people regret the high production of pollen by the grasses, for it gives them hay fever.

After pollination and fertilization occur, the fruit begins its development. It is one of the most interesting in all the plant world. In most plants we have little difficulty in deciding whether a structure is a fruit or a seed; we make the distinction easily enough whenever we shell peas or cut open a tomato, squash, or apple. In the grasses, however, the seed is fused to the fruit coat, so that what we usually call the "seed" of wheat is actually the whole fruit. This sort of fruit occurs throughout the grasses. We call it a "grain."

Photos by Cornelia Clarke and N. Y. Botanical Garden

The tall bamboos above are only very long, strong grasses. Their great strength is due to groups of especially strong cells that are formed in the stems in large numbers. Below is a stem of bamboo cut across near the point where a leaf comes off.



Everyone knows the common cereals so well that we had better journey to other parts of the world to catch a glimpse of unusual grasses. We may expect many of them to be very different from the ones we are familiar with, not only in appearance but also in use.

Perhaps the bamboo excels all other grasses in its many and varied uses. The bamboos are abundant throughout India, Southeastern Asia, and the Malay Archipelago, varying much in habit. Species with tall stems are common; others are slender and flexible; and many have a low, shrubby growth. They frequently form jungles of vast extent, dense and impenetrable, with a uniform appearance: for there are seldom more than two or three kinds of bamboo in the same jungle. The undergrowth is generally poor because of the deep shade. Some of the plants grow to a height of ninety feet, and have very strong stems. The great bamboo grows for the first two or three years as a clump of foliage, forming mostly roots. Then it begins to throw up gigantic stems—from thirty to a hundred in a clump—which may grow twenty to thirty feet during a single month.

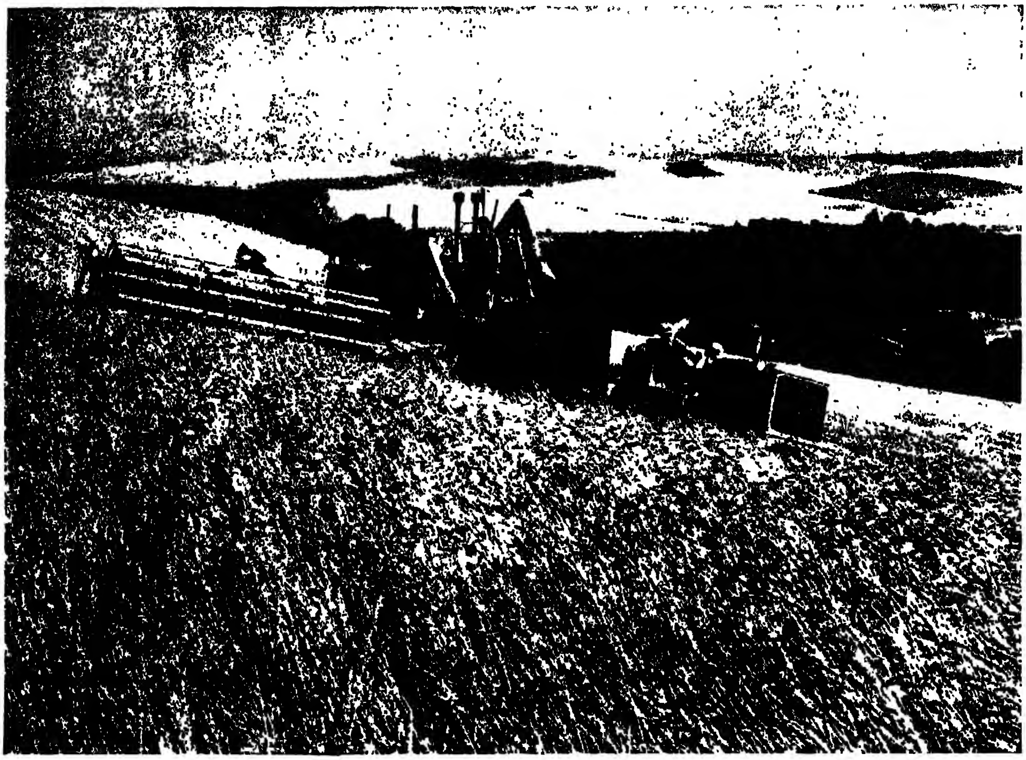


Photo by Caterpillar Tractor Co.

The raising of the humble grasses gives employment to millions of people in the world to-day. In primitive countries the rye and wheat and barley are still harvested in the way in which our ancestors harvested them for centuries. But wherever these modern machines have made their way the farmer is saved much of his back-breaking toil and bread becomes much cheaper. The American West is one of the world's greatest granaries, and the price of wheat spells happiness or disaster for millions of people.

In the countries where bamboos abound, they furnish much of the material used for building houses; the stronger and larger stems are used for posts and rafters, while the thinner stems are used for making floors and thatching and matting. In India, China, and Japan many domestic articles are made partly or entirely of bamboo. Its lightness, strength, and flexibility, along with its resistance to the action of water, make bamboo useful for many purposes. For example, bridges, parts of boats, bows, arrows, clubs, walking sticks, and fishing rods are made from the stem of this useful plant. The tender shoots of bamboo, either cooked or pickled, are used as food in China, Japan, and India, and are cultivated for that purpose. The Indians of the Orinoco and Upper Amazon use the stem as a blowpipe for their poisoned arrows. Owing to their buoyancy, bamboo rafts are very largely used for floating heavier timbers down the rivers Musical instruments such as flutes are made from especially selected stems, and the fibers of the stems are sometimes woven into a very coarse cloth.

A great many kinds of grasses besides bamboos have the same uses in other countries. In addition, there are numerous other purposes that they serve. The stems and leaves of many grasses are utilized in the manufacture of paper. Straw is largely used for making "papier-mâché." In the United States it is extensively used for the manufacture of strawboard, which has various uses.

Cordage is made in some countries from the stems and leaves of grasses. In Spain the manufacture of ropes and cables from leaves of esparto grass is an important industry, and these cables are so buoyant as to float in water.

Reading Unit No. 30

HOW THE PLANTS GOT THEIR NAMES

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why common names confuse students of plants, 2–182
How Linnaeus showed us how to name a plant properly, 2–182-85
Why a plant has two Latin names, 2 183-84
Why Latin was selected in naming plants, 2–183
Some common specific names, 2–184
Birth certificates for newly-discovered plants, 2–185

Things to Think About

Why do common plants have many different common names?
Why did Linnaeus decide that plants should have scientific names?
What makes Latin useful in naming plants?
How are plants named?
How can one learn whether or not one has discovered a new plant?
What do scientific names teach us about plant relationships?

Picture Hunt

Where did Linnaeus live? 2–182
Why is the "sacred lily of Africa" poorly named? 2-183
What is the Latin name for tulip? 2–184

Related Material

How did the name of the daisy originate? 2-174
How can a study of flowers give a clue to their real relationships? 2 162
Why are willows and poplars classified in the same family? 2–158
How did Linnaeus spend his life? 13–410-11

Leisure-time Activities

PROJECT NO. 1: Collect the leaves of ten trees and learn their Latin names by heart. Consult the bibliography. Collect as many names as you can for each plant whose Latin name you learn, 2–266-76.

Summary Statement

A plant may have so many common names that it is difficult to identify the plant by some of them. To overcome this difficulty, Linnaeus devised a method of giving two Latin names to each plant. The fact that Latin is a dead language and does not change makes it very useful in science. "Quercus alba" means "white oak" and nothing else, to scientists in Iceland, Africa, New York, Paris, Tokyo, or anywhere else.

Photos by Cornelia Clarke and American Museum of Natural History

Here is a field of daisies in Sweden, home of Linnaeus, the man who first gave plants scientific names. The daisy family is very large, and has many divisions or species. The Latin name of the genus to which our common American daisy belongs is *Bellis*, which means "pretty." Is it not well named?

HOW *the* PLANTS GOT THEIR NAMES

Why It Is Not Enough to Call a Plant a Snakeroot or a Bouncing Betty and Let It Go at That

IN ANY book about plants we may be worried from time to time by the strange names the writer gives them. Everybody knows a white oak, and what is the use of naming it a "Quercus alba"? Is anybody really going to call it that?

But now just think a moment. Do you know what a daffydowndilly is? Maybe you do and maybe you do not; certainly there are plenty of people who do not, and far more of them who have never heard that a daffydowndilly has a dozen other names as well—that in various places it is called an affodyl, an affodile, an asphodel, a lent lily, a jonquil, a saffron lily, and several other things besides a daffodil. And all these names are English. This same plant is known in many other countries where other languages are spoken, and in these other languages it has still other names. The whole situation is so confusing that unless they had some better system of names than the common names could afford, the botanists would hardly ever know what plant they were talking about.

The trouble has been that different people have given all sorts of names to the plants and flowers about them, without consulting one another or getting together to decide on a single good name that everyone would use for each kind of plant. The result is, for instance, that to this day there are seventeen different herbs which we call "snakeroot," and that each one of these kinds of snakeroot has other names in various parts of the world.

All this was so confusing that long ago—about 1753—the Swedish botanist Linnaeus (lĭ-nē'ŭs) decided it was too much of a nuisance. He set out on the vast work of giving every plant one single name by which every educated man could know it. But not exactly a single name either! He found it useful

to give each a double name, just as every person has a double name, like John Smith or Mary Brown. One of the names would be that of the large group or "genus" (jē'nŭs)—"genera" (jĕn'ĕ-rȧ) for the plural—to which the plant belonged, while the other would tell its particular species (spē'shēz). In a word, one name would be like "Smith," which tells the family concerned, and the other like "John," which narrows it down to a Smith with certain peculiar traits. In a similar way "Quercus" tells us we are dealing with an oak, and "alba" goes on to add that it is a white oak.

But what language was Linnaeus going to use? He was a native of Sweden, but how many people knew Swedish? If he used German or French or English, only a part of the people in the world could understand his names. But there was at that time one language in the world that nearly every educated man could read and speak, even though it had long been called "dead." That was Latin, the universal language of learning. So Linnaeus wisely decided to give all the plants Latin names, and that is why the scientific names of the plants are Latin to this day.

Photo by Cornelia Clarke

Here is a very strange flower which illustrates, among other things, how misleading even the prettiest popular names may be. It is called the "sacred lily of Africa"; but it is neither African nor a lily, and, as one botanist remarked, "anybody who once smelled it would hesitate to call it sacred." For at the pollination season it has an overpowering stench as of dead meat—which attracts the carrion flies that carry its pollen from flower to flower. This gigantic and unpleasant "lily" is a relative of our calla "lily" and our jack-in-the-pulpit.

Of course we can go on using the common English names, speaking of oaks and pines and lilies; that is all very well for every day. But if ever we grow to be scientists we shall want to escape from the confusion of all the popular names for plants, and then we shall take up the Latin terms of Linnaeus and find them far more convenient. With some practice we should cease to find these terms hard to spell or to remember.

To all the plants of any given genus Linnaeus gave a single name. It is their "generic" (jē-nĕr'ĭk) name, because it holds for the entire genus. Of course there are many genera among plants, for they run into many thousands. Here are some very common ones, English and Latin:

- Oak—*Quercus* (kwûr'-kŭs)
- Ash - *Fraxinus* (frăk'-sĭ-nŭs)
- Violet— *Viola* (vī'ō-lȧ)
- Dandelion- -*Taraxacum* (tȧ-răk'sȧ-kŭm)
- Rose—*Rosa* (rō'zȧ)
- Cabbage— *Brassica* (brăs'ĭ-kȧ)
- Fir— *Abies* (ā'bĭ-ēz)
- Pine—*Pinus* (pī'nŭs)
- Orange—*Citrus* (sĭt'-rŭs)

These generic names are always spelled with capitals and usually printed in *italics*. Now if we remember that what we call an oak has a hundred different common names between here and China, we can see that a single name like "Quercus," known to every botanist in every land, is of great convenience.

But that is only part of the work Linnaeus did. He knew that every plant must also have a specific as well as a generic name—that is, one that would tell its species in addition to its genus. So to the name of the genus he added, for each separate kind of plant, a name that would hold for its kind alone. This second part of the name was usually a Latin adjective which described the kind of plant it stood for.

For instance, let us take the oaks. There are two hundred different kinds, all belonging

Photo by Mt. Baker Lodge

Where flowers and bulbs are grown for the market, we sometimes see such magnificent sights as this vast field of tulips. But we do not have to go to Holland to see them, famous as Holland is for tulip growing—this field, for instance, blooms in the state of Washington. The tulip is one of the fairly large number of plants whose common and scientific names are much alike; its Latin name is *Tulipa*.

to the genus "Quercus." Here is what Linnaeus called some of the commonest kinds:

Name	*Meaning*
White oak— *Quercus alba*	*alba*—white
Black oak— *Quercus nigra*	*nigra*—black
Pin oak— *Quercus palustris*	*palustris*—swamp
Cork oak— *Quercus suber*	*suber*—old Latin for cork tree
Holm oak— *Quercus ilex*	*ilex*—old Latin name for this tree

In this way every plant got its specific name. Some of these are well known and others are less familiar. We can find these names in every nursery catalogue, in many a drug store, and in books of gardening and botany. Here are some of the commonest specific names we meet in such books. We come across these in many genera, but never more than once in any one genus. They are so common that everybody ought to know what they mean:

Specific Name	*Meaning*
acaulis (ȧ-kô'lĭs)	stemless
alatus (ȧ-lā'tŭs)	winged
armatus (är-mā'tŭs)	armed, as with prickles
caudatus (kô-dā'tŭs)	tailed, as in some seeds and leaves
coeruleus (sē-ro͞o'lē-ŭs)	blue
dulcis (dŭl'sĭs)	sweet
flavus (flā'vŭs)	yellow
gracilis (grăs'ĭ-lĭs)	slender
laevis (lē'vĭs)	smooth
pallidus (păl'ĭ-dŭs)	pale
serratus (sĕ-rā'tŭs)	toothed, as in many leaves
viridus (vĭr'ĭ-dŭs)	green

A Plant's Birth Certificate

If you were christened, your name was put down in the parish register, with the names of your father and mother and the date of your birth. If not in the parish register, then it was placed in a similar book in the courthouse.

Just so the two names of every plant are

set down in a book when a plant is "christened." For the plant, the priest or county official should be a scientist, and he should always set down in Latin a description of the plant he is naming—in order that every interested person in the world may find out just what it is like.

Linnaeus started this register for plants, in 1753, in his great book called the "Species Plantarum," or the "Species of Plants." Since then thousands of other plants have been christened and described in thousands of volumes from all over the world. Always the language is Latin, so that any educated man, whether he come from Sweden or from Japan, may read it. And that is how all our plants get their scientific names, for these books make up the record of all the plants that are known. There are great indexes to all the books, to prevent anyone from thinking he has found a new plant to name when he really has only come upon an old one that he does not happen to know.

These are the names that the doctors and druggists, the botanists and foresters usually use. Then each knows more exactly what the others are talking about. The scientific or Latin name also tells what other plants any given plant is closely related to. The common name, on the other hand, is often misleading on this point. The yellow poplar, for example, is not a poplar at all. The mountain ash is not a true ash, nor is the prickly ash one either, and poison oak is not an oak. These plants are not even distantly related to the poplar, the ash, or the oak family, but were given their common names probably because their leaves remind one slightly of the leaves of these families. The scientific names may seem difficult and strange to beginners, but when one gets used to them and realizes that, when once settled, there is only one scientific name for a plant instead of perhaps a dozen in each of a dozen or more different languages, he finds that it is much simpler to learn the scientific name.

Reading Unit No. 31

DO PLANTS THINK AND FEEL?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why plants lack feeling, 2–188
How the sensitive plant behaves, 2–189
How the cactus meets desert dangers, 2–189
How a magnolia tree imprisons an insect visitor, 2–189-90
How the magnolia insures its reproduction, 2–190
What makes plants survive and spread, 2–190

Things to Think About

How does human behavior differ from the behavior of a plant?
Why does the sensitive plant droop when touched?
Why must a cactus store water in order to survive?
How did the magnolia flower acquire its habit of trapping an insect?
Why do plants behave as they do?

Picture Hunt

Why do roots grow downward? 2–187
What happens to the leaves of sensitive plants at night? 2–188
How is the magnolia flower pollinated? 2–189

Related Material

How do vines hold to a wall? 2–154-55
How do reflex actions keep us alive? 2–393-94

Leisure-time Activities

PROJECT NO. 1: Buy the seeds of the sensitive plant from a seed store and sow them. When they are an inch high, see how they respond to a touch, 2–188-89.

PROJECT NO. 2: Fill a box with soil and plant radish seeds in it. Water only one half of the soil. Where do the roots go?

Summary Statement

Plants have no nervous system, but they react strongly to certain conditions around them. They respond to light, water, gravity, touch, and winds. A striking example is the sensitive plant, whose leaves droop on being touched. Plants behave as they do in order to survive.

Photo by Union Pacific Ry

This tough old pine, which stands on a rocky mountainside commanding a glorious view of Pike's Peak, Colorado, has managed to adapt itself to difficult conditions as cleverly as though it could really think out what to do. Between the crevices of the rock there has accumulated enough soil to give it a start as a seedling, and each year as the rock weathered and crumbled the roots have been able to absorb enough water and other materials for the tree to grow a little. The stem, as you see, grows upward in spite of its insecure foothold, and the roots, you may be sure, grow downward as well as they are able. For plants are sensitive to the pull of gravity, among other things, and it is gravity that makes most main stems grow up and most main roots grow down. So though it is stunted and weather-beaten, our pine has survived.

DO PLANTS THINK *and* FEEL?

By No Means as We Do; and Yet They Have Ways of Acting and Responding That Sometimes Remind Us of What We, Who Have Nerves and Brains, Are Able to Do

IF YOU happen to sit down on a tack you will jump up to your feet again like a flash. When you have to go out into freezing cold you will button up your overcoat around you as tightly as you can. And so with hundreds of other things that you do every day to keep from getting hurt, or to make yourself comfortable. You know perfectly well *why* you do all these things—so well that in many cases you hardly have to think about them. Your cat and your dog know about many of these things too—sometimes not so well as you do, and sometimes, it would seem, even better than you do.

For you and your cat and your dog can *feel* and *think*. You have a nervous system that makes you feel, and a brain that allows you to think. Many of the things you do are the result of feeling and thinking,


Photos by Cornelia Clarke

This is the sensitive plant, about which you may read in this story. In the picture at the left it has its leaves spread open, as they normally are during the daytime.

At the right it is seen with leaflets closed against each other, as they appear at night or when stimulated by pinching, wounding, or excess heat.

even though you may have done them so often that you no longer have to reason about them at all. There are many other things, however, over which you have little or no direct control. You cannot control the beating of your heart, the circulation of your blood, or the digestion of your food.

In plants there is no brain and no well-developed nervous system; so the plants cannot feel or think in the way that you and many animals do. And yet there are plants that will fold their leaves and droop if you barely touch them, and other plants that will catch an insect and hold him prisoner, even more expertly than you can catch a fly in your hand. Indeed every plant in the world has its own ways of doing things or of meeting or escaping danger. Often the danger is simply too much heat or too much cold, too much drought or too much wind. Sometimes it may be something else, like a grazing animal. In any case, different plants have in hundreds of different ways chanced to develop peculiarities that enable them to escape these dangers or to protect themselves from them. For a single instance, the cactus has modifications that enable it to live in a hot desert as well as can the camel.

Photo by Bert Huntoon, Bellingham, Wash.

When these trees were very young they grew upright, but probably the soil slid, tipping them over on their sides. The young tips then turned upward, making a bend in the stem. The old stem could not bend, so the crook remained.

Now the question is, how did the plants develop all these characters if they had no way of thinking or even of feeling? They do not know when it is too dry, and yet they may do the right thing when they have too little water. They can never see an insect or feel it as we do, and yet they may grab one far more skillfully than you snap up a fly on the window-

pane. How do they manage to do all this when they have no notion what they are doing?

Centuries ago, many a man believed that plants could think, and only recently the great Belgian author, Maurice Maeterlinck (mā'tĕr-lĭngk), wrote a book on "The Intelligence of the Flowers." But of course no flower has any intelligence at all, and Maeterlinck was only using a figure of speech. So we must ask again, what is it that plants do which looks so much like thinking?

Before we answer we had better give a few examples of the kind of thing a plant can do.

In tropical America there is a low, scrambling, weedy thing known as the sensitive plant. It has hundreds of tiny leaflets, each about a quarter of an inch long. These are set out in pairs along the stalk of each division of the leaf, and the foliage is almost featherlike from the number and fineness of the leaflets. Now if you barely touch one of these leaflets, it will instantly fold up against its opposite neighbor, and several of the other leaflets right around it will fold up too. If you strike the stalk of the leaf a tiny blow with a pencil, every single one of the leaflets on it will fold up in the same way, and the whole leaf will droop. And if you hit the main stem of the plant about as hard as you would strike a small tack with a hammer, all the leaves on the whole plant will droop at once. The plant will look unhealthy and very different from its neighbors. But half an hour later it will look all right again.

The plant has no notion what it is doing, or why. How does it come to act in this way? Well, like every other plant, it has to keep its leaves charged with water. If the sun is so hot, or the wind so strong, as to dry up the water too fast, the sensitive plant has its own way of holding on to the water in the leaves. Most of the other plants simply close the pores in their leaves; this one just shuts up its leaflets and lets them droop. It has no brain cells to tell it when to do this, but it has very sensitive cells of another kind which act when the sun is too hot or the wind is too hard, or when you strike the plant a little blow. The impulse runs through these cells almost as fast as one will run along your nerves to your brain. And the drooping follows.

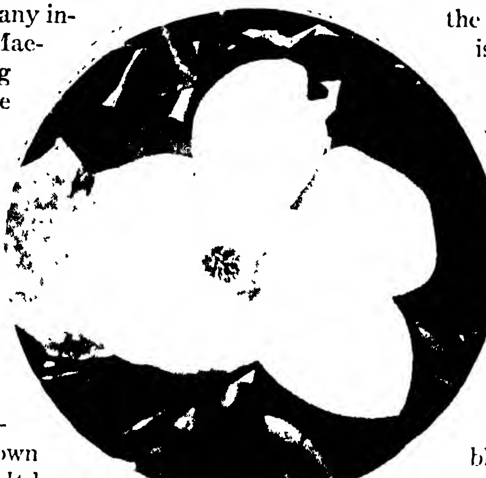


Photo by Cornelia Clarke

This is the beautiful flower of the magnolia. When an insect visitor brings it pollen from another flower, it closes over him for hours, until he has rubbed off all the pollen he brought with him and taken on another load to carry to the next magnolia he visits.

Of course it is a very different impulse from the one that runs along your nerves. You may see a blow coming and perhaps get out of the way. The plant can never do that; it can act only *after* the blow has fallen. You can even see pain coming and make up your mind *not* to get out of the way, but to face it without wincing. You do that when you go to the dentist. And the plant could never do that either; once it is struck, it must droop. But all this it does without ever knowing anything about what it is doing.

In the same way thousands of other plants have thousands of other tricks, many of which may be for their own good The cactus of the desert stores up its water and it may also have spines and thorns that are effective in keeping off grazing animals; and other plants have their ways of meeting danger in the changing conditions of air, water, wind, sun, and roving animals.

Here is one more example. On cool spring nights the sweet white flower of a certain magnolia tree will draw many a flying insect to it. The flower needs only one insect to dust pollen over its stigma, but it shuts up its petals on that one insect and holds him in for hours, until he has done his work well.

The insect has come from another magnolia flower; and flowers often do best if their stigmas catch the pollen from flowers of other plants.

At first the insect rather likes his nice chamber, and never dreams that he is really in a prison. He brushes off his pollen on the sticky stigma, and settles down for the night. In the morning he is ready to go on his way, but the magnolia flower has something to say about that. The flower has some stamens with their own pollen, and the insect must now get covered with another load, and take it off to another bloom. But the stamens are not quite ready yet to give up their pollen, and the insect has to wait.

Of course he does not like it. He wants to be on his way. He gets quite impatient, and buzzes around frantically trying to find a way out of his jail. By the time the pollen is ripe, perhaps several hours later, he is making a great fuss thrashing around—and so getting covered with a fine new coat of pollen to carry away to the next flower. And then the magnolia is finally ready to open her petals and let him go!

Can the Magnolia Really Think?

Now if we knew no better, we might think that the magnolia knew all along what it was doing, and did it all for its own purposes. That is what any savage would think about it, if he knew the facts. But we know that the magnolia cannot think, and cannot possibly know what it is doing. So we have to find another reason for all that the flower does.

The truth is that long, long ago there may have been plenty of magnolias which did not do these things. Therefore their stigmas did not catch the pollen from the stamens of other magnolias, or did not often catch it. So no seed developed in the magnolias, or at least the seeds were few and poor. But one kind of magnolia happened to acquire these tricks that made for good seed. Of course that kind of magnolia was likely to develop more or better seeds. Some of its children had the same tricks as their parent, and grew still further seed. And over a long period of time those magnolias which developed fewer or poorer seeds gradually disappeared, while that kind of magnolia which produced larger numbers of seeds, or better seeds, replaced the older variety and is still flourishing to-day; it is the kind of magnolia we have left.

What Makes a Plant Survive and Spread?

What is true of the magnolia is also true, in some way, of every other plant. Thousands of plants have started to live in the desert and have died of heat and drought or have been eaten by animals; the cactus happened upon the trick of storing up its water and of developing spines, and so spread all over the dry sands where we still find it. Thousands and thousands of plants have tried in vain to live in all the other parts of the world, only to find they were not fitted for it or not so well fitted as other plants which have crowded them out. All of those that are left are just the few which, in one way or another, happened to have the particular modifications that made it possible to live in those particular places.

All through the ages gradual changes, some small and some great, have been going on in all the plants. The changes are very, very slow, but there has been a long time for them to happen; so millions of changes have come to pass, to make all the varieties of plants the world has seen. If any change tended to make a plant less fit to meet the conditions under which it had to live, its chances for surviving were so much the worse. When a lucky change, or a lucky set of changes, made the plant more fit to live in its conditions, the plant survived and spread. All the marvelous things that the plants are doing to-day are the result of all of these changes down through the centuries, sorting out the plants that were to flourish. The changes are still going slowly on; and millions of years from now some of our plants will have disappeared as unfit, while other fitter ones will have appeared to take their places.

Reading Unit No. 32

HOW CLIMATE AFFECTS GROWING THINGS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How climate controls the distribution of plants, 2–192-93

How plants react to lack of water and to heat, 2–193-95

How plants live in the Arctic, 2–195-96

Winter and summer forests, 2–196

Where frost is never known, 2–196-97

How rainfall creates prairies and deserts, 2–197

Things to Think About

How can a plant fight conditions of drought?

Where do our great evergreen forests thrive?

What is meant by a deciduous forest?

How much annual rainfall do tropical forests get?

Under what conditions will trees give way to prairies?

Picture Hunt

How can plants live in a desert? 2–192

How has climate affected plant geography? 2–193

How does sunshine affect flowering in cosmos? 2–194

How does wind affect pines? 2–195

Related Material

Why do cacti have few leaves? 2–33

How do we know there was once an Ice Age? 1–5

How do flowers behave when it is 70 degrees below zero? 2–205-7

What desert plant can quench a traveler's thirst? 2–206

Why do plants need light and water? 2–46

Leisure-time Activities

PROJECT NO. 1: To study the effect of sunshine on plants, plant seeds of the primrose, cosmos, or some other plant in pots. Keep half of the pots out of doors, the other half indoors. Compare their growth and flowering, 2–194.

Summary Statement

Plants live where they do, not by accident, but because the climate forces them to do so. In the jungles, where there is much rainfall and no frost, plants reach their finest development. As we go north, we find forests which drop their leaves during winter because frozen water cannot get into the roots. Further north, we find evergreen forests, and then mere dwarf trees, which flower rapidly and then go back to sleep again.

Photo by Los Angeles C. of C

Dry as this sandy plain is it is still bright with flowers. For some plants have extensive or deep roots which absorb any water to be had; and the leaves and stems can store much moisture and lose it slowly.

HOW CLIMATE AFFECTS GROWING THINGS

From the Rank Jungles to the Icy Arctic, There Is a Reason Why Every Plant Grows Just Where It Does

WHEN the weather man tells us that the thermometer is at 90°, the humidity at 89, the wind velocity almost nothing, and the barometer at 29.90 inches, you and I know that it is a very hot and steamy day, and we are most uncomfortable. But most of the trees and other plants love such a day, for then conditions are ideal for them. We hope for better days to come, but the trees and other plants do not.

If we grow too tired of the climate, we can move away to another. We can go south in the winter, or to the mountains or seashore in the summer, just to escape the bad weather. And many other animals travel with the weather even more than we do. But no tree can leave its place and seek a better clime. It must stay at the mercy of the weather in the place where it first took root.

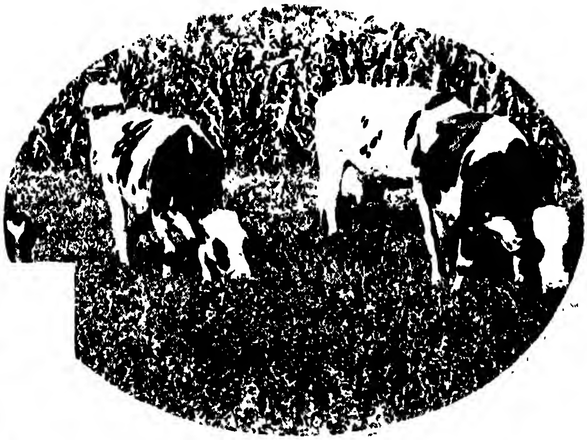
But if plants are at the mercy of the weather they are by no means indifferent to it. They are really far more sensitive to it than men are, and that is why they are scattered around the world in a very different fashion from men. For although no single plant can ever travel, whole races of plants in forests, prairies, and deserts, have been crowded out of certain countries and have moved away to others just because of changes or differences in the climate. Climate is simply the total of all the weather day by

day, and plants are found only in the areas where the climate allows them to live. It is not merely acci-

dent that the fir grows in Northern Canada, the palm in Brazil, the grass on our prairies, and the cactus in the desert. The climate, past and present, has had a great deal to do with this distribution.

The weather man gives us a daily record of the temperature, the sunshine, the humidity, the rainfall, and the direction and speed of the wind. He has no one instrument that tells him all these things. But any roadside weed or tree is sensitive to such conditions. There is no change in temperature or humidity, in wind or sunshine, which does not influence the plant. In fact, the plants are so marvelously sensitive to such changes that many a scientist has used them as a measure of the changes.

Of course plants are also very sensitive to the amount of rainfall. They usually get all their moisture out of the ground. Wilting and death are the extreme signs of too little water, especially when a plant used to having plenty of water suddenly finds itself without it. But when a plant has to live through a long period of insufficient water



On this page are trees and other plants from many climes, from the frozen Arctic to the Tropics, from the desert to the steamy jungle. First is a stately fir, which grows in the cold northern woods or on the cool uplands of the Temperate Zone. Then, in the oval, are cattle grazing on alfalfa, which grows on the temperate prairies, while back of them wave the tops of a taller grass which we call corn. To the left is a cactus, native of dry regions in tropical or subtropical lands. And in the circle is the feathery palm of the Tropics.

Photos by U. S. Department of Agriculture

Photos by U. S. Department of Agriculture

These pictures illustrate two experiments which a scientist has made to show what happens when plants do not get the sort of weather to which they are adjusted. At the left are two plants of the evening primrose, which thrives best when it has long periods of sunshine. The tall, healthy plant has had all the sunshine it needed, but the little one has not had enough and so has not developed properly. At the right are two plants of cosmos, which does not like long sunny days. Again, the tall plant has had much sunshine and the little one not so much. But the small plant, which grew in the condition of little sunshine, normal to the cosmos, is in the best of health, with buds about to break into flowers; and the big plant, which had more sunshine than cosmos needs, has put all its strength into unnatural leaf and stem growth, and will not be able to flower at all. So it is clear that a plant is healthiest in its own sort of climate.

supply, it will usually develop other less extreme signs of distress. The leaves are likely to have grown smaller, thicker, and more compact, to have various protective coverings of felt or varnish, or, in extreme droughts, to fall off altogether. Sometimes when the air is dry and the wind is high, a plant will lose so much water through its leaves that it may be in great danger of its life.

How Temperature Affects Plants

Plants are also sensitive to changes in the heat. Whenever the temperature goes down, most of the life processes of the plant are slowed up. This may not be of much harm to many plants, except in making them grow more slowly. But some plants, especially those which have always grown in warm regions, will gradually sicken and die if they are kept cool very long. If the temperature goes still lower and the plants are actually frozen, most of them will be killed if they have not been rather gradually accustomed to low temperatures. The buds of most woody plants and the leaves of evergreens that naturally grow in temperate or cold regions are not injured by the extreme cold of the winter. If they should be frozen in midsummer, however, when they are not ready for cold weather, most of them would be killed outright.

Often plants also suffer from too high temperatures. Usually the high temperature injures the plants because it makes them lose water too rapidly; but sometimes the heat kills them directly. Many of our common plants are not killed if exposed for a short time to temperatures around 110° to 115° F., but are seriously threatened if the

Photo by Cooper & Cooper, Denver

On many a rocky mountain top, where soil is scarce and bitter winds sweep past day after day, stands a sturdy pine such as this—stunted and twisted and gnarled, but triumphantly alive. It is bent almost double from fighting the wind, and its small size and few needles speak eloquently of its unfavorable surroundings. But here it stands like a sorely-tried sentinel, dark against the snowy horizon.

temperature gets much above 120°. Such high temperatures are rare in regions where most plants grow; though in direct sunshine the temperature at the surface of the soil fairly frequently approaches this danger point. In fact, in some regions seedling plants in large numbers are killed because of the heat at the surface of the soil. Older plants shade the soil, or the cork on their stems acts as an insulator and prevents excessive heating.

Two Important Conditions in Climate

Above all the other conditions in the climate the two that are most important for the plants are the rainfall and the heat. Upon these two depend the distribution of vast belts of vegetation all around the world. And now let us take an imaginary journey from the Pole to the Equator, and so cut across the various belts, or "zones," of plant life.

At the Pole we find almost no plants at all. There are six months of nearly continuous sunlight, but there is so much ice and so little chance for plants to grow that there are only a few algae (ăl′jē) that can live on the snow or in the water. But as we come only a few miles southward, though we are still well within the Arctic Circle we meet with a great change.

Science has shown us that the last great ice sheets which once covered all of Northern Europe and America have gradually retreated northward. To-day there are thousands of square miles left of these ice sheets, often hundreds of feet thick. But on the surface of many of them there is now a layer of soil often two or more feet thick. In this soil, which is frozen solid for about ten months of the year, there are many plants. They have become used to having their roots just above perpetual ice, and to doing all their flowering and fruiting in the short growing season of scarcely sixty days. Then they become dormant for another ten months.

The Plants That Live in the Arctic

We might hardly think that any plant would stand such treatment. But there are over a hundred different kinds in these cold places—all of them low shrubs or perennial herbs, with very few annuals. Dwarf willows and birches abound, but no real trees are found there, for they could not stand against the bitter winds and ice storms. These plants of the Arctic "tundra" (to͝on′drȧ), as the places on top of the ice are called, are

often very interesting and beautiful. We may also see these plants, or their close relatives, on the peaks of the Rocky Mountains or the Alps, where some people think they got stranded in the old days when the ice sheets were creeping back to the north, many a year ago.

The Great Forests of the North

As we travel south from the tundra we begin to find queer stunted trees, often less than a foot tall but perhaps over a hundred years old. It is still very cold for most of the year, though not quite so cold as in the tundra, and the growing season, or the period from spring to the cold of winter, is longer. These poor stunted trees are nearly all spruces and firs, very much like dwarfed Christmas trees. As we go still farther south, the trees begin to get taller, and when we get still farther down, they have grown very large indeed. And now we find some new ones, for we are in the heart of the great evergreen forests of the north.

Regions such as this have a growing season of about three or three and a half months. But in that period the forest is very active. New shoots, looking like great green candles, start up all over the trees, for plenty of moisture and the long days of sunshine make possible rapid growth as well as early flowering and cone making. Nearly all these evergreens are firs, spruces, junipers, and hemlocks, and they all bear cones which are not injured if they cling to the twigs over the whole winter, or even over several winters. Nor are the seeds of such trees hurt by the snow and ice which the trees must endure for about nine months of the year.

What Is a Summer Forest?

These evergreen forests are best suited to such climates because they can carry on their work in spite of the long cold season. All they need is plenty of moisture during their brief growing season. When this is lacking they simply do not grow at all. What will then replace them we shall see in a moment.

The evergreen forests are sometimes called "winter forests," since they stay green all the winter. But south of them for hundreds of miles there is another sort of forest that has been called a "summer forest," because only in the summer is it green. It is also called a "deciduous" (dĕ-sĭd'ū-ŭs) forest, which means that it drops all its leaves in autumn. Whatever we call it, it is the familiar forest that most of us know best. It is the great forest of the Temperate Zone, where the winters may or may not be severe, but where the growing season varies from five to ten months.

Instead of only a few kinds of evergreens, there are hundreds of species of oak, birch, maple, ash, willow, and dozens of other trees. Like the evergreen forests farther north, this summer forest also needs plenty of rain in its growing season, and where the rain is lacking we always find something else in place of the trees. Both sorts of forest depend on rain and heat. The evergreen simply gets a longer winter and the summer forest a longer growing season. Both must be able to stand frost, which some kinds of forest never can stand.

Places Where Frost Is Never Known

All around the middle of the world stretches a belt in which frost is never known except on the tops of the high mountains. The only place in the United States which comes within that belt is Key West, in Florida. South of this, stretching nearly all the way to the Argentine, there is a region over four thousand miles wide that is always warm. But of course it is not all equally warm; it gets cooler in uplands and hotter in the great tropical valleys, like that of the Amazon.

It is in the steaming hot valleys of the Amazon and Congo, in some parts of India, and in most of the islands of the East Indies, like Borneo and Java, that we find the frostless forests in their perfection. Palms and queer, strangling fig trees, giant trunks with wicked hooked prickles, and millions of herbs and bamboos are crowded together in the densest confusion. So thick is the canopy that the forest floor is as dark as the dim interior of a great cathedral.

In these forests, always hot and often receiving 100 to 200 inches of rainfall, which is from three to five times the rainfall of New York, we find the utmost that Nature can produce in the way of vegetation—all

its luxuriance depending on the rain and the sun.

Now of course these different belts, or zones, of vegetation do not stretch evenly around the world, like the bands of color on a painted flowerpot. Anyone who lives in the prairie states or in Arizona, in Northern Africa or Northern Australia, knows that very well. At many points on our way from Pole to Equator we do not find quite what we might have expected. Why should there be millions of square miles of grassland in North America, in Russia, and in the Argentine? And why are forests found near all of them? And why should parts of Arizona and New Mexico, of the Sahara and of Australia, be deserts? All of these places are very hot, some of them have never known a frost, and yet trees are almost unknown in them. Why is that?

Plants can no more thrive on heat alone than we can. Wherever the rainfall gets below a certain point--about eighteen inches a year in the United States—trees cannot grow. They may sometimes be found in locally wet places, or where they have been planted by man. But the trees cannot get a start and thrive in such dry places, and in their stead we find dense grasses. Millions of square miles of the earth's surface are covered with prairie grass, tall or short. There could be no better example of what the weather does to our plants. It has crowded out the trees altogether. And the plant world has done the next best thing it could-- it has covered the area with grass, which can stand the lack of moisture.

But prairies also need a certain amount of rain, and there are some regions that do not get enough even for grass. In our own Southwest there are thousands of square miles where the yearly rainfall is only from two to ten inches, and in some places even less. Here we find few or no grasses and of course no trees at all. But we do find the strangest, queerest plants, mostly with poor leaves or none at all, and often very thorny. Here we meet the giant cactus and hundreds of its leafless relatives, and all over the world we find plants very like them in this one particular—they can live and flower with so little rain as to make us wonder how they grow at all.

We call all these places deserts, but the botanist does not quite agree to the word. He knows that the plants in such places have a hard time, but after all he sees that there are some plants growing there. He will tell us that a true desert is one where there is practically never any rain at all, and never any plant. The only place in the world where this is true is up in the Andes of Peru and Bolivia. On these bleak mountain uplands there is not one living green thing to be found. Several botanists have gone there just to study the effect of climate on vegetation. For not so very far away are the richest forests in the world. And as the traveler goes down the Andes toward them he will pass from this absolute desert, through the cactus country that most people would still call a desert, into the wonderful upland pastures of grassland. Then he will begin to reach the trees, just as we did south of the tundra. And finally he will come to the dread jungles of the Amazon. In that journey, shorter than the distance from New York to St. Louis, our botanist will have seen a remarkable illustration of what the weather does for plants.

BOTANY

Reading Unit No. 33

FLOWERING PLANTS THAT LIVE IN THE WATER

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How water plants get sunlight, 2–200

How water plants are classified, 2–200

The water lily, 2–200-1

Why some water plants have ribbon-shaped leaves, 2–201

Why leaves of water plants are feathery, 2–201

How water plants float, 2–201

Things to Think About

How do seaweeds differ from other water plants?

What three groups of water plants are there?

Why can the leaf of a water lily always float on the surface?

Why are the stems and leaves of a water plant filled with gases?

Picture Hunt

What plant has its roots in the mud and its leaves on the surface of the pond? 2–199

What can people do with the fruits of the water lily? 200

What water plant has leaves that may support a man? 2–201

Related Material

Why do water plants need carbon dioxide? 2–41

Why do leaves have stomata? 2–26

What is a leaf like inside? 2–26

How do ocean plants live? 2–66-69

Leisure-time Activities

PROJECT NO. 1: Visit a pond or stream with a net. Carry home a variety of water plants. Wash them in a swift stream to remove harmful insects, and plant them in your aquarium. Observe their habits of growth and their structure.

Summary Statement

Water plants have fewer problems than land plants because water varies less in temperature than air does. Water plants, as a rule, have few or no stomata through which gases may be released. Gases are retained and help the plant to float. Many leaves are ribbon-like to escape tearing. Some plants have their roots in the mud and their leaves afloat; some plants are wholly submerged, and some float at the surface.

Photo by C. B. & Q. Ry

One longs for a canoe to paddle softly among the water lilies of this lovely mountain lake! We should stoop—very carefully--and gather some of the flowers, which are not really lilies at all but relatives of the buttercup. Both the flowers and the leaves of this aquatic plant float on the surface of the water. There is a long green stem, and roots which are fast in the earth at the bottom of the lake.

FLOWERING PLANTS THAT LIVE *in the* WATER

How They Have Developed Many Curious Features to Fit Them for Their Watery Homes

THE vast majority of our flowering plants are land plants. They usually live by holding their shoots and flowers in the air and by forcing their roots through the soil. The stems usually support leaves which expose a large surface to the air and light. The roots are usually embedded in soil with various degrees of moisture, from which they absorb their water and minerals. For several reasons water is absolutely necessary for all living things, and any active or growing cells must have a large amount of water in them.

We find flowering plants adapted to all sorts of water conditions. At the one extreme there are plants which can withstand long periods of dryness and are capable of flourishing under desert conditions where the water supply reaches its minimum. At the other, we find plants that have completely forsaken life upon land for life in the water. Between these extremes, we find plants which normally are land plants but can endure occasional submergence, and others which normally live in water but can exist for short periods of time out of it. It is the water, or aquatic (ȧ-kwä'tĭk), group in which we are now interested.

FLOWERING PLANTS THAT LIVE IN THE WATER

When we think of aquatic flowering plants, we usually picture those we find growing in the shallow, quiet waters along the edges of ponds and lakes, or in the still eddies of streams. These are the places where we do find most of our water plants. But there are a few which grow in the shallow salt water along the seacoasts. Such plants as sea wrack and the fine, threadlike Ruppia can be found mingled with seaweeds of many kinds, but usually can be distinguished from them easily —because the seaweeds, or algae (ăl'jē), are not flowering plants, and do not have true stems or roots or flowers, as do most plants.

Photo by N. Y. Botanical Garden

Ten thousand acres of yellow pond lilies! Here we see a corner of this vast watery garden in a high mountain lake. The fruits of the plant produce many seeds, which the Klamath Indians of the Northwest dry and roast for food.

The conditions in which our aquatic plants exist are different from those of our land plants. The temperature variation is never so great as that of air; it never gets so low or so high as air temperature. This is indeed important for some plants.

How Light Is Important to Water Plants

Water plants, like all others that are green, must get some light. Some are dependent upon direct sunlight. They must have at least a few hours of direct sunlight each day and are never to be found in shaded places. Others, such as some of the bladderworts and pondweeds, perish when subjected to strong illumination. In general, submerged plants live in light conditions much like our "shade" plants on land, which seem to thrive only in diffuse light.

You will remember that there are certain gases in the atmosphere that the plant needs, at certain times at least, to carry on important processes. These gases are oxygen and carbon dioxide (dī-ŏk'sīd), and aquatic plants need them as well. In order that the gases may be at hand for the water plants, they must be dissolved in the water. But there is usually not so much oxygen dissolved in water as there is in the atmosphere. The water plants have developed a way to meet this condition; we shall describe it later. But there is usually plenty of carbon dioxide in the water, since the supply is ordinarily maintained by decaying organic material.

If we could see all the different kinds of aquatic plants growing in their natural haunts, we could readily place them in three general groups, though there would be exceptions. In the one group we should place such plants as the common water lily; they have leaves and flowers that float on the surface even though the plant may be anchored under water. The second group would consist of plants which spend their entire life completely submerged. Some of these are not even rooted, but pass their life floating in the water—which is to them what the atmosphere and soil are to the land plants. In the third group we find such plants as the pondweeds, which have their stems and leaves and roots under water, but their flowers above it, at least at pollination time. These changes in habit are associated with marked changes in structure. All parts of the plant seem to have undergone considerable change.

Perhaps the leaves show as much change as any part of the plant. All of us have seen the floating leaves of our common water lily; we call them lily pads. Without these plants many of the ponds and lakes would be much less attractive. Insects and frogs find them convenient islands on which to sun themselves. If we examine a pad closely, we soon see that it is rather leathery and tough. The shape usually is circular or oval, and the petiole is attached near the center.

Photo by Field Museum

These great leaves, which look like enormous shallow saucers, belong to *Victoria regia*, a water lily which grows in the Amazon River in South America. Once in a while, though not very often, this water lily will produce a leaf big and strong enough to hold up a man—as if it were a raft. Specimens of the great plant are often grown in greenhouses because the leaves are so unusual and therefore so interesting.

If we try to pull a leaf from the water, we find that the petiole is very flexible and can stretch for some distance. These traits seem to be found in most floating leaves, in adjustment to the motion of water and the dashing effect of rain

The Great Variety of Submerged Leaves

Submerged leaves seem to show a much greater variety than floating leaves. Some are thin and entire and ribbon-shaped, while others are finely divided or perforated. The ribbon-shaped ones seem to be very resistant to tearing. Such is the shape found among many of those plants that grow along with sea algae, where they are subjected to the wash of waves and tides. Leaves of this sort are sometimes very long; they have even been found to measure two yards.

The subdivided leaf is commonly found in such plants as hornworts and water milfoil. The segments may be fine and delicate or they may be large. In many species they resemble spines or needles, and are marked in curious ways. The perforated (pûr′fō-rā′tĕd) leaves are very strange ones, and have been found only on a few tropical plants. There is one found in Madagascar which is most interesting. The leaf begins in a normal, oval shape, and has the usual flat, expanded blade. But after a short time all the soft tissue of the leaf drops away, leaving very little more than the skeleton. Bit by bit the tissue disappears, and the delicate framework of veins stands out alone. The feathery skeleton is so fine that we naturally call the plant the "laceleaf." Another name is "lattice leaf," for the bare veins are so regularly arranged that they look like a delicate lattice.

Accompanying the change in general appearance of these submerged water leaves, we find certain internal changes. Generally the leaves are rather thin and delicate, and upon removal from water they usually wither rapidly. We find, moreover, that the leaves have few or no stomata (stō′mȧ-tȧ) and hairs. The aërating system of aquatic leaves is a very conspicuous one. This system is formed either by the breaking down of cells in the leaf, or by the pulling apart of cells as the leaf develops. In either case, large spaces are formed which become filled with gases. The occurrence of two or more kinds of leaves upon a single plant has long attracted attention. We find it characteristic of certain water plants.

The stems of aquatic plants show the same general types of reduction as leaves do. Aided by large spaces filled with gases, they are thus relieved of the task of supporting the weight of the branches and leaves. This allows for the development of a rather weak stem, with comparatively little supporting tissue.

Reading Unit
No. 34

THE PLANTS THAT WEAR ARMOR

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How the cactus became prickly, 2–203-4
Why prickly desert plants survive, 2–204
Plants with thorns and deadly poisons, 2–205
Why some plants go to sleep in cold weather, 2–205-7
The truth about "manna," 2–207
The resurrection plant, 2–207

Things to Think About

How does armor help a plant to grow and multiply?
Why have cattle growers wished for a truly spineless cactus?
Why are loco weeds dangerous?
How can some plants live through severe Arctic winters?
How does the manna lichen escape dry conditions?

Picture Hunt

Why do cowboys fear certain cacti? 2–203
Why do cattle leave the pods of jimson weed alone? 2–204
How does a certain kind of ant save the acacia tree? 2–205
How may a cactus save a man's life? 2–206

Related Material

How do plants know what to do in order to grow and multiply? 2–187-90
How does the sensitive plant protect itself? 2–188-89
What success have we had with spineless cacti? 2–167
How do porcupines defend themselves? 4–381

Leisure-time Activities

PROJECT NO. 1: Make a cactus garden in flat pans. Use as many varieties as you can, 2–206.

PROJECT NO. 2: Make a collection of the following: Stems of black locust, honey locust, blackberry, raspberry, rose, and stinging nettle. Press them and mount them on labeled cardboard for exhibition.

Summary Statement

Plants cannot run away from enemies, but they can keep enemies away with thorns, spines, poisons, or other means of defense. Cacti are good examples of armored plants. Acacias and certain palms are thorny. The manna lichen has no thorns, but curls up in dry weather and is blown away by the wind to moister places. Some plants close up in the dry season, opening only during the rainy season.

Photo by Field Museum

This dangerous-looking cactus grows in the Peruvian Andes, in South America; it has close relatives in our own country. Not only is such a cactus heavily armed with spines and bristles, but its branches are attached so delicately to the main stem that they break very easily and sink their spines into anything near them. Because they break so easily Arizona cowboys sometimes say that "they jump at you."

The PLANTS THAT WEAR ARMOR

Why It Is That Some Plants Can Keep the Grazing Animals from Eating Them

WHEN a knight of the Round Table put on all his armor he knew very well how much he would need it to protect him in battle. Without his chain mail and his steel helmet he would not last long.

Now many a common plant has a suit of armor just as effective as that of the knight. And more than this, the plant may have even better ways of making men and animals let it alone. For there are some plants that animals will rarely touch.

It is all too easy to say that the plants *developed* their various kinds of armor *in order* to protect themselves from the animals. Very often we hear people say something like that. But it is not true, or at least this is not the way to say it. For no plant can think, or ever know what it is doing; no plant could ever grow a suit of armor *with the purpose* of protecting itself from its enemies.

So the right thing is not to say that "the cactus has developed horrible prickles," but that "horrible prickles have developed on the cactus." Then the kind of cactus that had the worst prickles was the best-defended from its enemies, and had the best chance to grow and multiply. That is the way Nature works, and that may be why the cacti without prickles died out while those with prickles lived and spread.

You must not think this is merely splitting hairs or playing with words. It is not. The net result—a prickly cactus—is just the same, whichever way you say it. But the first

statement is just loose talk, while the other comes very near to the true facts in the story of plant protection—quite as near as modern science dares to come in trying to interpret Nature's doings. With this clearly in mind, we can now go on to see what Nature has done to give many plants a better suit of armor, for her purposes, than any knight in steel ever had.

The one great fight of desert plants is to get and keep enough water to live. In some regions there is only an inch of rainfall a year, and on millions of square miles of the earth's surface there are no more than five or ten inches. That is not enough for a forest or even a grassland to live on.

In those regions we may find a weird collection of plants, often with no leaves but with very fleshy stems, and quite often with a great capacity for storing water. In our story about stems we have seen how our cacti store their water. In the Old World, where there are no native cacti, some of the plants have a similar power of storing water. Of course this stored-up water is very precious.

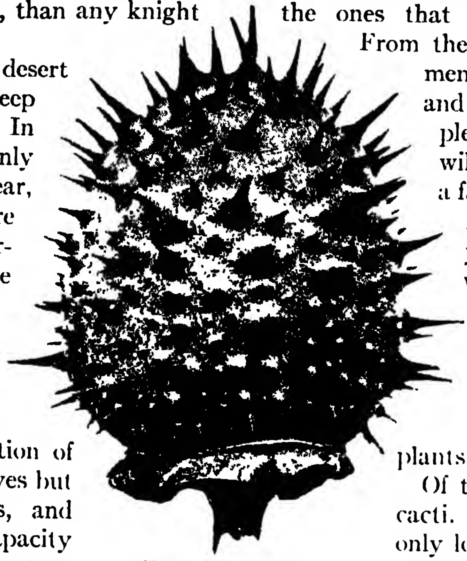


Photo by Cornelia Clarke

The jimson weed is not uncommon in vacant lots or other waste ground. Its fruit, the spiny capsule shown here, is well named the thorn apple. It is not merely spiny but extremely poisonous to eat!

Now in desert regions the animals also have a hard time finding water. Many of them perish for the lack of it, and many fight for the chance to use a rare water hole. For there is no grass, or only such tough, wiry tussocks as will furnish very little water. Among such animals the fight for even a little green stuff is as bitter as the fight for water. If all desert plants were as luscious as grass or cabbage leaves, they would all be gone in a few days. But although the interior of most desert plants may be richer in food and water than any cabbage leaf, the animals will have great trouble in getting at it. It is far too well protected from their teeth.

For long ago the desert plants hit on ways of keeping their food and water safe from the animals. Little by little they grew horny coats or varnished surfaces, developed enough green coloring matter in their stems to get along with undeveloped leaves, or grew spines or prickles; and the animals let them alone.

Of course the plants that grew these were the ones that survived and flourished. From them has come the development of a whole race of prickly and thorny plants, so completely armed that no one will tamper with them. In a fairly short time, as Nature measures the passing years, such prickly plants will change the whole vegetation of a region. For all fresh green plants will disappear from such a land, and only the tough, thorny desert plants will be left.

Of these the greatest are the cacti. Some of them have not only long spines, but, as in the prickly pears, another sort of armor in addition. Besides the prickles, which sometimes fall off in certain seasons, they have at the base of each prickle a cushion of little bristles. These may look innocent enough, but any animal that brushes against them will soon find how innocent they are! For each bristle is really a barbed dart, so arranged that it will easily come off and go into your skin, but can be pulled out only with difficulty. Of course no animal can ever get them all out, and the animals leave prickly pears severely alone. The bristles usually come out in bunches of six or eight, and they are so fine that one can scarcely see them. Because of these barbs they may work their way through gloves or clothes.

The Prickly Armor of Desert Plants

Not all the desert plants are so spiny as the cacti, but hundreds of them have such long, sharp prickles that it is next to impossible to get near their few green leaves. Even some of the palms have on their trunks hun-

dreds of downward-pointing thorns that tend to keep animals from climbing up. In one of them, in Brazil, each thorn is about a foot long and very sharp. Just think of any man or monkey trying to reach their fruit!

It is easy to see why some plants have been helped by the devices they have developed to protect them from losing too much water. But there are certain other kinds of protection that are harder to understand. We do not yet know why plants like the poison ivy or the blister bush of South Africa have a juice of the kind that makes your skin itch. It would never do to say that they just need protection from picking by man, because they are not plants that would be likely to be destroyed by him. Then, too, some of the animals can eat them without suffering at all.

Many other plants have still more dangerous poisons. But there is no proof that these deadly juices help them by protecting them against use by man. Many of their poisons are perfectly harmless to their chief enemies, the grazing or nibbling animals.

Here is a small part of the stem of an acacia which grows in Costa Rica. The stipules at the base of the leaf are modified into the stiff thorns you see in the picture. These thorns are the homes of a certain kind of ant which lives on a nectar found just below the leaf blade. These ants fight with and drive away other ants which come to cut through the leaf and destroy it. So the ants in the spines protect the acacia from the other kind of ant, which would destroy the leaves and therefore the plant itself.

Many of the herbs in the grazing lands of America and of Australia are never touched by careful animals. There are a dozen kinds, such as the loco weeds, the stagger bush, and the death camas (kăm'ăs), that will either kill cattle outright, or, as in some of the loco weeds, cause a disease called the "blind staggers." The poor animal that has eaten them will stagger like a drunken man, for its nerve centers are slowly deadened by the juice.

Many grazing animals seem to have learned to leave these plants alone, and therefore the herbs are not destroyed and become very plentiful. Being so common, they are a great menace in times of drought, when the animals may be so starved as to eat almost anything. Driven by hunger, the creatures may lose their sense of what is good and bad forage. Then the poor beasts on the great ranges, far away from friendly barns full of food and water, are driven to eat these poisonous weeds, just as shipwrecked men will drink sea water. How many of the animals are lost in this way you may guess from the government figures of the yearly losses. Every year the Department of Agriculture and the cattle owners kill millions of these weeds. But the yearly loss of cows, sheep, and horses still runs into many millions of dollars.

In Northern Siberia there is a place that is supposed to be the coldest spot in the world. In winter the temperature hovers around 70° below zero, and the winds are terrific. A group of scientists came near dying there once because the winter caught them before they could get away. In such a place the brief summer gives plants only a short time to flower and set their seeds. And sometimes a few of the plants, like the scientists, get caught. One of these herbs was in full flower when winter came down from the Arctic with a rush of icy wind. Some of its earlier flowers had already turned to half-ripe pods, but most of its delicate white petals were still fully opened when the winter came.

In the spring, nearly nine months later, a strange sight met the scientists. There was

THE PLANTS THAT WEAR ARMOR

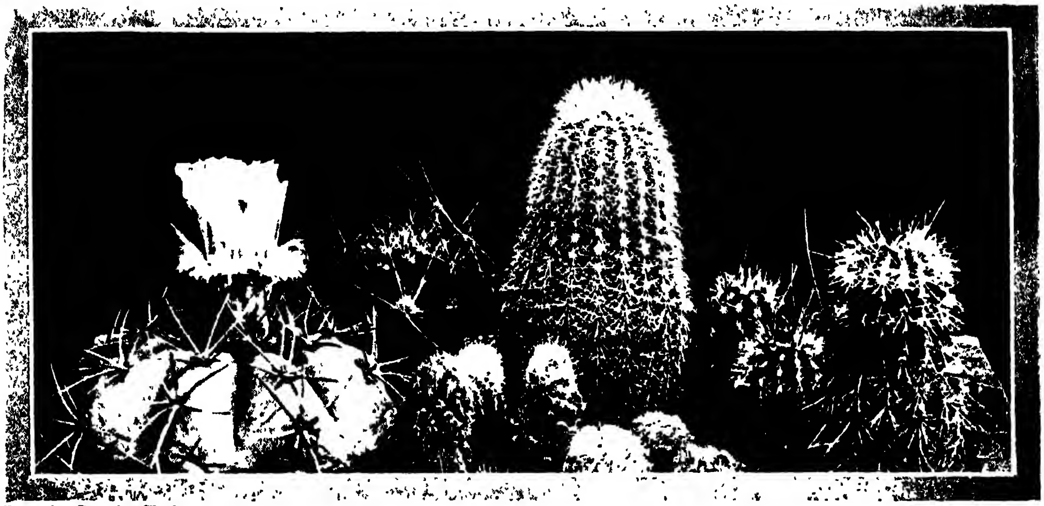


Photo by Cornelia Clarke

No plants are better armored than the cacti, as we can very well imagine from the picture above. These are only a few of the many varieties of this armored family, most of which have spikes or prickles of varying degrees of viciousness. It would be a brave animal that tried to crop any of them! Very probably you have pricked your own fingers on one or more of them, even if you never saw a desert in your life. For a few years ago people rather suddenly decided tha' the weird shapes and awkward poses of cacti were amusing and artistic in a "modernistic" way; and now we grow thousands of them in our homes.

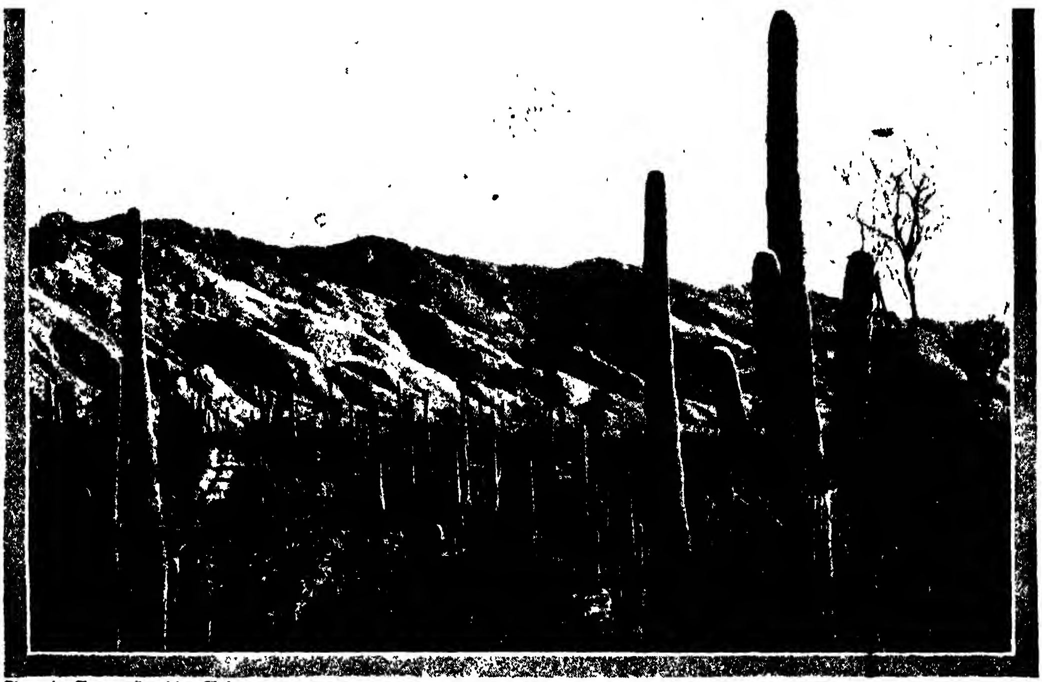


Photo by Tucson Sunshine Club

The cactus family is almost altogether confined to the tropical and subtropical regions of the Americas. Here is a whole army of the giant cactus standing guard over the desert in the Southwest. A man would look very tiny at the foot of one of these great armored plants. Yet the Indians gather the fruit by means of a long forked pole and use the crimson pulp for food. Cacti have also furnished many a thirsty desert dweller with life-giving drink—after he has broken through the tough skin to the stored water. Both medicines and intoxicating drinks have long been brewed by primitive people from cactus stems.

the little white-flowered herb, perfectly well and happy, its petals not in the least hurt. Its pods were not shriveled. It looked and acted as if it was quite ready to go on with its long-delayed business. And that is exactly what it did.

Of course its petals, pods, and leaves had been frozen. But it simply protected its living tissue by going into a long coma (kō'mȧ), or resting period.

Many herbs much nearer home than Siberia have this sort of protection. They are even able to stand the much more difficult trial of alternate frosts and thaws. They may seem to be doing nothing to protect themselves, but there are very important chemical changes going on in their cells. It is these hidden changes that make possible the living death. That "sleep" is just as much of a protection to the plant as thorns or poisons.

"Playing 'possum" against cold is not the only kind of protective dormancy, or "sleep," that has been developed in plants. Equally useful dormancy against drought is found in regions that have plenty of rain in one season but none at all in the next season.

Plants might easily die in these droughts if they had no way of meeting the danger. One of them not only does meet the danger, but incidentally gives food to wandering tribes in the regions where it grows. It is a lichen (lī'kĕn) which is fairly plump and perfectly active during the growing season. But as the drought appears it begins to curl up from the rock on which it grows. It gets to be a shriveled thing, and begins to lose its hold on the rock.

The more the hot dry wind blows, the looser the plant gets, until finally it blows away altogether and is at the mercy of the wind. That may seem a queer sort of "protection." But listen to what happens.

If the plant kept flattened out on the rock it would certainly have been killed by the heat and drought. But by curling up and allowing itself to be blown away it manages to keep alive, though only dormant. In this dry state it provides food for people, for this lichen is one of the plants we call "manna." It is blown about in great quantities, and the poor wandering tribes, often hard-pressed for food, are glad to make a meal of it.

Growing in much the same regions with the manna lichen is the "resurrection plant." It, too, goes through a protective dormancy, but of a very different kind. In dry seasons the plant is rolled up into a tight ball of what looks like leafless twigs. But the plant is an herb and has no twigs. In its fresh state it is a leafy herb about six inches across, with plenty of small compound leaves and small flowers and fruits.

When the dry season begins, it starts to curl its leaves inward. The plant keeps this up until it is a tightly-compressed ball of withered leaves, only an inch or two in diameter. It may keep this shape for months, looking perfectly dead. But it is by no means dead. If a small shower comes it begins to unfold its tightly-pressed leaves, but only a little, as if it wanted to make sure the shower was not a false alarm. If the rain *is* only a shower, the plant will roll itself up into a tight ball again. There may be any number of these false starts, but each time the plant shuts up again if there has been insufficient rain.

Finally the rainy season comes in earnest. Then the resurrection plant really unfolds its protective ball. Then, but not till then, it sheds its seeds.

The swordlike leaves of the pineapple can give the brown skin of a bare-legged Hawaiian native a very ugly gash.

A pineapple's spiny-margined leaves are not successful in keeping man away, but they may keep grazing animals from eating them.

Reading Unit No. 35

SOME STRANGE WAYS OF SCATTERING SEEDS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How weeds have been scattered by man, 2–210
How wind carries seeds and fruits, 2 210-12
Seeds and fruits that float away on water, 2–212
Seeds and fruits that steal rides on animals, 2 212-13
Seeds that are shot out of the fruit, 2 213-14

Things to Think About

How are weeds often spread to different parts of the earth?
What structures help some seeds and fruits to travel great distances?
Why has the Russian thistle become a pest?
Why do we often find wild cherry trees growing under wires and beside fences?
Why is the sandbox tree a menace?

Picture Hunt

What use does man make of a fruit's ability to float? 2–209
What seeds have their own parachutes? 2–210-11
What fruit often steals a ride on an animal? 2–211
How are berries planted in nature? 2–212
How is the castor-oil plant distributed? 2-213

Leisure-time Activities

PROJECT NO. 1: In September collect some large milkweed pods and put them into a dry box. Open them later and learn what the seeds can do, 2–210.

PROJECT NO. 2: Examine with a hand lens fruits of tick trefoil and other fruits that cling to your clothes—such as burdock, cockleburr, and beggar's ticks. What helps them to cling? 2 211

PROJECT NO. 3: Put some witch-hazel fruits into a cigar box. What do you hear from time to time? 2–211

Summary Statement

Plants must scatter their seeds and fruits. Otherwise, overcrowding would kill the new plants. For that reason, those seeds and fruits that were lucky enough to get such structures as wings, parachutes, air floats, hooks, and explosive devices have been able to survive. The rest died out. Certain weeds have spread over all the world by various means; many have been helped by man's carelessness.

Photo by Bureau of Agriculture, Philippine Islands

This great collection of coconuts, in the Philippines, has of course been assembled by man. For coconuts do not make themselves into rafts and float accommodatingly off to market. But it is true that the coconut is, for a fruit, an unusually good sailor—or rather floater. Sometimes a single coconut will fall from such palms as these into the water, and drift away for many miles to some distant land. Men have merely taken advantage of the fact when they get coconuts to market in this simple way—by floating them.

SOME STRANGE WAYS *of* SCATTERING SEEDS

How They Are Carried by Birds and Animals and Breezes, or Are Even Shot Off from the Plants That Bear Them

MOST of us have wandered through fields and woods often enough to have noticed something about how plants are distributed in different places. Some are found in closely-growing clumps or patches, while others are more widely scattered. One may find that large areas of forest land which have been cleared of trees by fire or lumber companies have been covered by flowering plants not to be found elsewhere in the neighborhood. Fields that lie fallow for only a few years may soon be covered also with large numbers of flowering plants.

Practically all our flowering plants reproduce by seeds which are borne in fruits of one sort or another. Since plants are widely scattered, this must mean that in some way the seeds, or the fruits in which the seeds are borne, have been scattered. If we study the life cycles of our various wild flowering plants, we shall find that there are a number of ways by which the scattering is accomplished. Often the seeds are spread only for a short distance from the parent plant, but in some plants they may be carried great distances, even for many miles. Let us see what some of these various methods of distribution may be.

Perhaps man has played as great a part

in the extreme distribution of seeds and fruits as any one agency. In most cases, this distribution has been unintended, as when seeds of many weeds are carried and planted with those of useful plants. In the days when large groups of colonists migrated from one place to another, they often carried with them large quantities of seeds for their plantings. In this way, many kinds of cultivated plants as well as weeds associated with them were widely distributed. The United States has many plants that originally came from Europe and other countries, and Europe has many that the crusaders of the olden times brought from Asia. Even at the present time plants are carried from one country to another. Many governments have men stationed in various parts of the world collecting plants which may be of service.

The carrying of seeds and fruits of our wild plants seems to be less intentional today, though it does often occur. Raw materials shipped from one country to another may carry seeds. We get a great deal of wool from Argentina, and frequently in the carding and cleaning of it, seeds and fruits come out. Commercial seeds which may be shipped long distances may contain foreign seeds. Shipments of hay and unground feed may contain seeds of plants that were not intended to be carried. The ballast and packing material from freight cars and boats carries with it many kinds of seeds. It is not at all surprising to find plants growing in freight yards and near wharves from seeds dropped from such material.


Photo by Cornelia Clarke

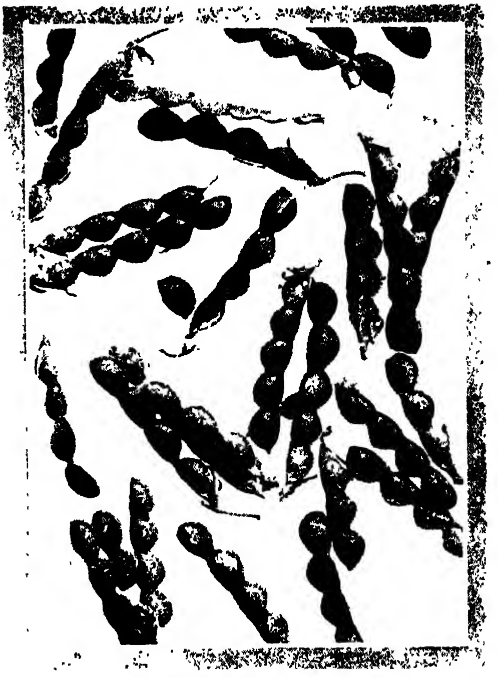
The pretty white fluff that bursts from the pod of the milkweed contains little seeds, each with a tuft of hairs at its top. This fruit is so feathery and light that it can float long distances on the wind, and in that way sow new milkweed plants far away.

Wind is an effective agent for carrying many seeds and fruits. A common type of seed or fruit that is carried by wind is one that develops hairs or bristles or scales which aid in its floating from one place to another. The seed of fireweed and milkweed, and the fruit of the dandelion, are tufted only at one end, while the seeds of willows and poplars are covered with hairs. In the common thistle the hairs spread widely and are quite fluffy. Some seeds, such as those of Catalpa and Hibiscus, are tufted at both ends.

The seeds and fruits that are winged are usually heavier than those with hairs or bristles. Generally they are borne on trees or shrubs. As they drop from the plants, they slowly descend like whirling propellers and may thus be carried many yards before reaching the ground. We find such seeds in elms, maples, birches, and many other plants, and often we can see them fluttering to the ground. In the hop plant, the seed is in the basal portion of a rather large fruit scale. The chaff that we find in many of the grasses acts as wings and aids in the carrying of their fruits.

SOME STRANGE WAYS OF SCATTERING SEEDS

The fruit of the maple tree, here cut in half, floats on two wings formed by its outer coat.



The tick trefoil fruit has a jointed pod so hairy and sticky that it clings to passing animals.

Photos by Cornelia Clarke and Nature Magazine

Each of the tiny fruits which make up the dandelion's head carries a single seed with a feathery crown of hairs by means of which it rides the wind.

A puffball, being a kind of fungus, does not have seeds, but it sends its dustlike spores into the air by an eruption as of a miniature volcano.

SOME STRANGE WAYS OF SCATTERING SEEDS

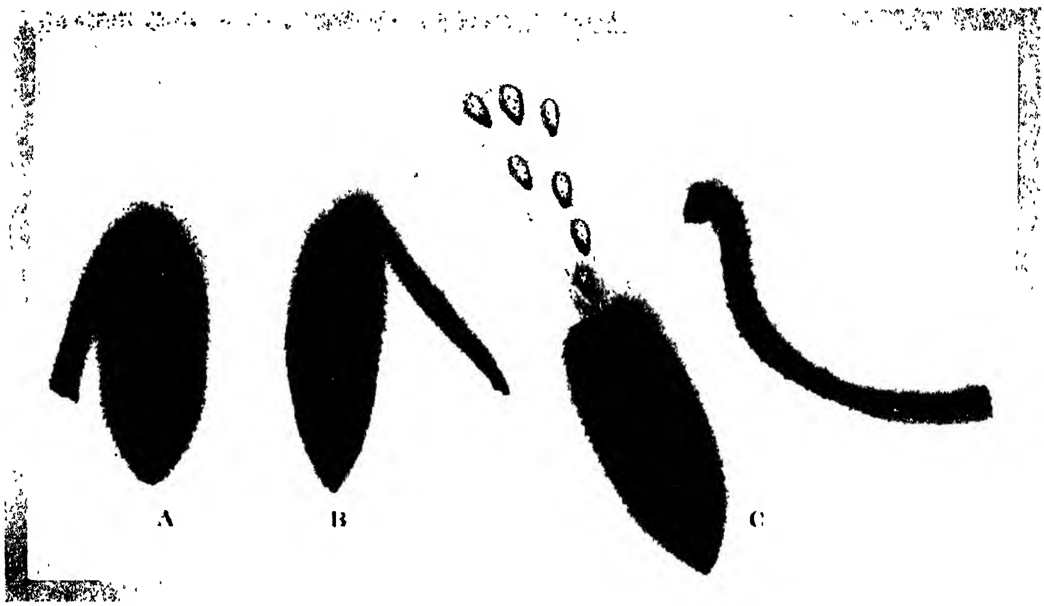


Photo by British M

As the fruit of the squirting cucumber (A and B) ripens, the tissues in which the seeds are buried break down into a mucilaginous mass that absorbs water and therefore develops a pressure inside the fruit. There is a weak spot where the end of the stem fits into the fruit; so when the ripe fruit breaks off at this point, the seeds and juice are squirted out of the fruit, as shown at C.

There is still another group in which the wind helps to disperse the seeds and fruits. We generally call these plants tumbleweeds. Among them the Russian thistle, pigweeds, and peppergrasses are the most common. After the seeds have ripened, the plants easily break from their roots and are rolled about by the wind, losing a few seeds at a time. Commonly these plants have an oval or spherical shape, and a gust of wind will roll them about easily. With the Russian thistle, which may have as many as 200,000 seeds on a single plant, this proves to be an effective method of scattering the seeds over wind-swept plains.

Many of our water plants, and plants growing along shores or banks, have a curious means of seed and fruit dispersal. The seeds float. A common floating device we find in the sedges. The fruit is supported in an envelope which is filled with air, and so it is able to float much as we do when we use "water wings." The seed of the water plantain and the fruit of the flowering rushes have distinct corky layers which enable them to float for days without sinking. Coconuts and other tropical fruits are said to be carried great distances by water. Coconuts have been known to float a thousand miles in ocean currents before being washed upon land.

We have all come home from a walk through the fields and woods only to find our clothing covered with seeds and fruits of various plants. Most common of these were the sticktight, beggars' lice, cocklebur, and burdock. In all of these we find hooked or barbed projections from the seed or fruit or the parts in which they are inclosed. Not only do we carry seeds and fruits in that way, sometimes for considerable distances, but various animals also carry many seeds in their fur or hair.

Photo by U. S Department of Agriculture

Birds are attracted by the bright colors and juicy flesh of such fruits as berries, and while they are gorging themselves they do the plants a great service. Either they carry off the fruit—with the seeds in it—before they eat it, or they eat the fruit and later drop the indigestible seeds, quite uninjured, in some distant place.

Photos by Cornelia Clarke

Here are two fruits the botanist calls capsules. Each pops open suddenly when it is ripe and throws out its seeds. At the left is balsam, or touch-me-not; at the right the castor-oil plant. The latter has a second device for distributing its seeds—a spiny fruit coat likely to catch on any passing animal.

Birds also have been found to carry seeds on various parts of their bodies, and even insects may carry certain kinds for short distances. In the tropical countries ants have been seen moving seeds.

We have mentioned that birds sometimes carry seeds on the outside of their bodies. They also carry some on the inside. For there are many kinds of fleshy fruits, like raspberries, mulberries, and elderberries, which are eaten by birds. The seeds inside these fruits are generally indigestible because of their hard coats, and may be carried great distances before they pass through the digestive tract.

Among the most remarkable means for dispersal of seeds are those in which the plants themselves scatter the seeds without the help of wind or animals. In these plants the seeds are forcibly ejected from the plant, though usually not for very great distances. There are two general ways in which plants throw their seeds.

Man, after all, is responsible for the distribution of many seeds. This fine statue of "The Sower," by Sir William Thornycroft, stands in the famous Botanic Gardens at Kew, not far from London.

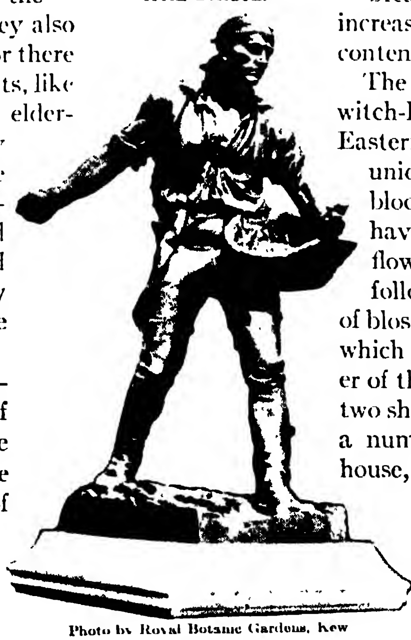


Photo by Royal Botanic Gardens, Kew

In the one group the fruits are usually dry, and split or burst when they are ripe. It is this sudden splitting or bursting of the fruit which throws out the seeds. The breaking is usually due to an increase or decrease in the water content of certain cells of the fruit.

The shrub from which we get witch-hazel grows commonly in Eastern North America, and is unique because its yellow flowers bloom in autumn after the leaves have fallen. The fruits from the flowers do not ripen until the following autumn. At the time of blossoming, the woody seed case, which has developed from the flower of the year before, is ripening its two shiny black seeds. If you bring a number of seed cases into the house, where they will dry out, they gradually split open at the top. The heavy, shelled seed case, as it dries, presses tightly on the smooth, hard seeds until,

one at a time, they suddenly shoot out from the seed case and may fly clear across the room. These seeds are shot in much the same way in which you can shoot a melon seed or an apple seed by pinching it between your thumb and finger, except that the witch-hazel seeds have a harder seed coat, are dry, and may be shot farther than you can shoot watermelon seeds.

One has to keep pretty quiet to hear the explosions of witch-hazel pods. And it is harder still to hear the shooting of the seeds of the violet, of the castor-oil plant, or of the touch-me-not. These and many other plants shoot their seeds for considerable distances, but mostly without much noise. In the West Indies, however, there is a tree that one does not have to listen for. One may hear its explosions popping like pistol shots if one is fortunate enough to be on the spot at the right time. It is called the sand-box tree because the sections of the fruit are filled with "sand" that our ancestors used instead of blotting paper.

The fruit consists of about fifteen of these sections, which are in shape and size much like the sections of the orange. Each section contains a single seed. When the fruit is ripe there are terrific strains set up between each section and the common stalk to which they are all joined. This goes on for some time, until finally there is a very loud report. The fruit literally explodes, shooting the sections in every direction and far from the tree. This is the most violently explosive of all fruits, and shoots its seeds further than any other known plant.

Seeds driven with so much violence ought to be worth all the trouble the plant takes with them, and the tree itself is worth spreading. But seeds of the sand-box are so poisonous that they are deadly to men and animals; if they happen to fall in a pool they will even kill the fish that live there. This means that they are generally let alone, no matter where they land.

Can you see why the sand-box tree is so common? It has a combination of qualities that few plants can boast. There is, first, the best seed gun known in the plant world. Then, as a final guarantee that the seeds shall survive, they are so dangerous that none are likely to be eaten or touched.

In Impatiens (ĭm-pā'shĭ-ĕnz), or touch-me-not, the fruit coat splits and rolls up with a snap, and as it does this the seeds are flung out. The wild geranium treats its seeds in the same way. The pods of some of the vetches sometimes split, each half snapping back rapidly and kicking its seeds out.

The squirting cucumber has a very queer way of distributing its seeds. The fruit has the appearance of a small, rough cucumber. It is usually about an inch and a half long, and so covered with hairs that it cannot be eaten. When the seeds are ripe, the tissue inside the succulent cucumber is broken down into a semi-liquid mass. As the fruit ripens, the outward pressure of this liquid grows so great that the fruit almost bursts. About this time the fruit falls from its stalk. And when it breaks away, the point at which it was attached to the stalk is for the first time exposed to air. Now at this point there is a weakness in the covering of the cucumber. When the fruit falls away from the stalk, the pressure of the liquid inside bursts the cucumber at this point. As it falls, the semi-liquid mass is forced through the base of the fruit. Sometimes the mass may be squirted a yard away.

The other group of plants which eject their seeds we call the "sling" group. These plants depend almost entirely upon the elasticity of their stems and fruit stalks, which are set in motion by either animals or wind, and the seeds are shot off as from a sling. Certain plants have such devices as lattice work or teeth, which permit only one seed, or only a few, to pass at a time, thus insuring the dispersal over a longer period of time. This method we find in poppies, in the large flowered beard tongue and in some of the vetches. Combined with this sling mechanism, some plants have a device for protecting their seeds against wet weather. In such cases the openings through which the seeds are thrown have valves which remain over the opening when the air is moist and curl away when the air is dry.

Reading Unit
No. 36

DOES A PLANT EVER SLEEP?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How long do seeds sleep in the soil? 2-216-17
Why some seeds fail to germinate, 2-217
How seeds may be forced to germinate, 2-217-18
When buds, bulbs, tubers, and corms grow, 2-218-19
Using ethylene to speed flowering, 2-219

Things to Think About

What causes seeds to lie dormant for years?
Why is treatment of the seed coat of value in planting seeds?
What are the chances of seeds' germinating by themselves?
When will twigs open their buds?
How do fruit growers use poisonous gases?

Picture Hunt

Why can some plants do without leaves in winter? 2-216
How long do most evergreens keep their leaves? 2-216
What plant may be used to study sleep movements? 2-217
When do plants go to sleep? 2-217
What advantage have seed plants over ferns? 2-218

Related Material

How are seeds scattered in nature? 2-119-20
What are monocotyledons? 2-143-44
How does temperature affect plants? 2-194-96

Leisure-time Activities

PROJECT NO. 1: Buy a small package of morning-glory seeds. Sow half the seeds in soil in the usual way. Scratch the seed coats of the rest with a file before you plant them. Water both lots daily. Which lot comes up first? Why? 2-217

PROJECT NO. 2: Sow seeds of the sensitive plant (Mimosa). When they are one inch high, watch the behavior of the leaves at night, on cloudy days, and when touched, 2-217.

Summary Statement

Plants undergo a rest period. In the fall, many trees drop their leaves. Seeds, too, rest, and may do so for many years, until they meet proper conditions for germinating. Bulbs, buds, tubers, and corms undergo a rest period also.

Photo by Cornona Clarke

When a tree has dropped its leaves in winter, we know it must be at rest, or dormant, for it is not growing and has no leaves that could be manufacturing food. The evergreens are dormant too, even though they still hold their leaves, which make some food during the warmer bright days. Most evergreens keep their leaves, or needles, for three or more years, letting the oldest ones drop off each year. The trees in the picture above will put forth buds and shoots in the spring, after the sap has begun to flow.

DOES *a* PLANT EVER SLEEP?

And if It Does, Do We Know Any Ways of Wakening It?

WHERE do all the weeds come from that keep appearing, especially after rains, even though you have killed all the young plants as fast as they came up? Large numbers of them come from seeds that have been lying dormant in the soil for a year or more—perhaps for eight or ten years, and in some cases for much longer periods.

If you have never wondered about that, perhaps you have been startled, after planting what you thought were living seeds, to find that few or none of them ever came up. That is likely enough to happen with seeds belonging to the pea family, such as those of sweet clover, vetch, or even peas or beans. Seeds of many shrubs and trees also fail to grow when newly harvested. Common kinds that behave in this way are dogwood, barberry, peach, apple, basswood, juniper, hickory, and walnut. Sometimes, of course, the seeds fail to germinate (jûr′mĭ-nāt), or start growing, because they are dead; but it is possible for many kinds of living seeds to remain in a warm, moist soil and still fail to germinate for periods ranging from a few weeks to several years. There are a few cases on record in which seeds that have been in the soil for from twenty to two hundred years are still living, and will show vigorous growth if first treated to bring them out of their dormant, or resting, condition.

We occasionally hear stories that grain found in old Egyptian tombs has been planted and found to grow, but these probably are

all false. Yet it is true that many common seeds can be kept alive for five or ten years—and some even up to twenty-five or a hundred years—if they are kept thoroughly dry, and that these will usually germinate at once when placed in a warm, moist situation. Their failure to germinate has been due to nothing in the seed itself, but largely to an environment which has been too dry to allow germination or sprouting. Those seeds that fail to germinate in a soil which would seem to be best suited for vigorous growth usually do so because of some peculiar condition in the seed itself. Several different kinds of treatment have been found necessary or at least helpful in hastening the germination of these dormant seeds.

Leaves of some plants show what we call sleep movements; at night or sometimes on very dark days they lose their horizontal position and droop, or the leaflets fold against each other – sometimes upward with their upper surfaces together, sometimes downward with their under surfaces together. Here are "sleeping" leaves of the wood sorrel.

Many seeds fail to germinate because the seed coat is waterproof, and thus prevents the necessary water from getting into the seed. These seeds, even though planted in a moist soil, are kept dry inside and fail to grow. A very good way to cause the germination of these so-called "hard seed" is to injure the seed coat in some way. This can be done by cutting the coat or scratching it, by blowing the seeds against roughened surfaces, by treating with strong sulphuric acid, by storing in a humid atmosphere for several weeks, or even by boiling the seeds in water for about a minute. The seeds of many of the plants belonging to the pea family, such as vetches and clovers, have hard seed coats that will not allow water to enter. Even peas and beans will sometimes germinate very slowly unless the seed coat is softened. Cotton seeds often have to be treated to soften the hard coat. Seeds of the Indian lotus, which have been found in old peat beds in Manchuria, and which have probably been lying there for from two hundred to five hundred years, will germinate at once if the hard seed coat is cut.

It has been a common practice among many nurserymen to place the seeds of many woody plants in layers of soil or sand, leave them outdoors over the winter, and then plant them in the spring. Such "stratified" seed often germinate much better than seed not so treated. It used to be thought that repeated freezing and thawing broke the seed coats or otherwise stimulated the seed, but it has recently been found that it is not the freezing and thawing which does the work, but that the seeds are brought out of their dormant or resting condition by being kept for some time at a temperature slightly above freezing. Even removing the seed coat completely may be useless in starting these seeds. Many such seeds, however, can be brought out of their resting state, and may actually start growing, if they are planted in moist soil and are then kept in a refrigerator for one to three months. After they have been kept at a low temperature long enough, they can be planted in a warm soil and make a vigorous growth. The best temperature for hastening the germination of these seeds is from about 35° to 45° F. Temperatures considerably below freezing are not effective in hastening the germination of the seeds, while summer temperature seems to throw the seeds back into the resting condition again if it is applied before the seeds have been cold long enough to break their rest.

Under natural conditions in the woods, the seeds are exposed to widely different conditions. Some of them fall into protected hollows where they are covered by leaves or snowdrifts; by spring they will have been

exposed to temperatures different from those of other seeds which may have been lying on the surface, or in some animal's burrow. Those seeds which have been exposed for the longest time to temperatures just above freezing are the most likely to sprout in the spring, while the other seeds may lie for a year or many years before they are exposed to conditions necessary for germination.

There are many kinds of seeds that are helped by this cold treatment. Many plants belonging to the rose family, such as roses themselves, thorn apples, apples, and pears, usually require a low-temperature treatment, as do also plants belonging to very different families, such as dogwoods, barberries, sugar maples, and even junipers—which belong to the distant pine family.

There are still other classes of seeds that require other kinds of treatment or are at least greatly helped by them. Some fail to germinate unless exposed to light for a period. Some require a high oxygen supply, others a low oxygen supply, and some are greatly favored by alternating high and low temperatures, but with the low temperature considerably above freezing. Perhaps most of the seeds that go through this rest, or dormant condition, are in that condition when they first ripen. Some seeds, however, are capable of germination at once, but will enter the resting condition if kept for a time under certain conditions unfavorable for growth. One method found effective with wild mustard seeds is to store them in an atmosphere with a high content of carbon dioxide gas—the gas which both animals and plants give off as a waste product of their respiration. This gas prevents the growth of many seeds, and puts some seeds into the resting condition. In order to wake these seeds up it may be necessary to cut off the seed coat or dry the seeds out and resoak them. The soil often has quite a high content of carbon dioxide gas, and for this reason is probably sometimes effective in putting seeds to sleep. When the soil is disturbed and the seeds are dried out on the surface, a later rain may find them ready to sprout and send up a new crop of plants.

Photo by Cornelia Clarke

Many a seed, like this one of a common garden bean, lies for a long time dormant—a word which literally means "sleeping"—until it finds itself surrounded by just the conditions favorable to its growth. Then the sleeping life within it awakens, and it begins to grow. In these pictures you can follow it through the earlier stages of that growth. The seed in the lower left-hand corner has been cut open to show the two cotyledons as they look at the beginning, fat with their stored food. Lying on one of them is the little new plant, all ready to break out and send its stem upward and its roots downward. It is shown in the other pictures. This marvelous ability of seeds to lie dormant until conditions are right and then to awaken is the chief advantage the seed-bearing plants have over such seedless plants as ferns, algae, and fungi.

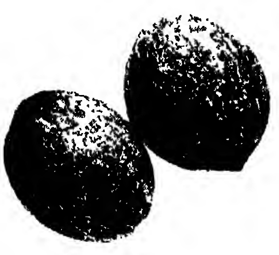
This ability to lie asleep, or dormant, even when surrounding conditions are favorable for rapid growth, is not limited to seeds. The bulbs of many plants, such as tulips and

daffodils, the "corms" of the gladiolus, the tubers of potatoes, and even the buds of most of the woody plants of temperate regions, pass through a resting period during which they will fail to grow. A freshly harvested potato, if planted in ordinary soil, may lie dormant for two or three months without sprouting. If, after the leaves have fallen in the autumn, you bring the twigs of many kinds of woody plants into a warm house, and stand them in water, you will find that very few of them will open their buds. They are in the resting condition. If you wait till spring, however, twigs from the same trees may promptly open their buds when brought into a warm place. These buds behave somewhat as do those seeds that fail to sprout until after they have been kept for some time at a temperature near freezing. Some of these woody plants, such as certain kinds of lilacs and certain apples and peaches, fail completely or do very poorly when transplanted to regions where the winters are not cool enough to wake them out of their rest. They seem to require cold weather to wake them up for vigorous growth.

With woody plants it has been found that many different treatments are often effective in waking them out of their rest. Many of these treatments are such as are likely to be injurious to the plants, especially if carried a little too far. It seems as if partial injury serves to wake the sleeping buds, perhaps as a pin prick or other injury will wake you. Pinching, rubbing, or pricking a resting bud is likely to wake it, as is also exposure to temperatures high enough to cause slight injury. Exposure to somewhat poisonous substances, such as chloroform, ether, ethylene, acetylene, some alcohols, hydrocyanic acid, smoke of burning paper or wood or other materials, is also likely to start growth. Some tropical plants even change their habits when given these treatments. A few years ago a pineapple grower in Porto Rico found that some of the pineapples near which he had had a smoky rubbish fire developed fruits about a year earlier than the plants in the rest of the field. He therefore tried giving smoke smudge to whole fields, and found he could have ripe pineapples months ahead of his neighbors. This gave some botanists the idea that ethylene (ĕth′ĭ-lēn), which is likely to be present in such smoke, might be the cause for the waking of the flower buds of pineapples. Such has proved to be the case, and many growers in Porto Rico are now using this treatment to hasten the flowering and fruiting of pineapples.

We see then that many kinds and parts of plants have a dormant, or rest, period during which they will not grow unless they are given special treatment to wake them up. Many seeds have dormant periods of this sort. We can see how this habit may be of great value to the plants; for if all the seeds germinated when the conditions about them were favorable, none would be left to germinate later if a frost or a drought should kill all those which first sprouted. As it is, a seed which has been lying in the soil for many years may start growth when the soil is disturbed and the seed coat injured enough to wake it from its long rest. If all seeds would germinate as soon as the soil is moist and warm, you would not have to keep killing off new crops of weeds that have come up since the last time you hoed the garden. The rest in buds of woody plants, and that in bulbs and tubers and other underground storage stems and roots, keeps them from sprouting in the warm days of autumn and early winter only to be killed by later freezing weather.

These two coconuts, so well protected by their stout shell, may be borne along for years by the ocean current, with nothing to wake them from slumber.



Once come to port on some fertile shore, the sleeping coconuts will awaken and send up shoots, their first step in the process of growing to be lordly palms.

Reading Unit No. 37

WHY THE FLOWERS BLOOM WHEN THEY DO

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What makes some plants form seeds ahead of time, 2-222-23
How vegetable growers prevent the flowering of celery, 2-222
Experiments with cabbage growing, 2-222
How light affects flowering, 2-222-23
Short-day and long-day flowers, 2-223-24
How length of day affects bird migration, 2-224

Things to Think About

How did celery growers find a way to prevent flowering?
When will cabbages form flowers instead of leafy heads?
Why do some plants flower in the spring and others in the fall?
How can one grow a giant cosmos plant?
What may ruin a beet crop?

Picture Hunt

Why do mountain flowers bloom all at the same time? 2-221
Why is it hard to grow beets in the tropics? 2-222
Why are spring and late summer the best times to plant lettuce? 2-257

Related Material

How can you make flower buds on twigs open up? 2-219
Why do plants have flowers? 2-101-4

Leisure-time Activities

PROJECT NO. 1: To study the effect of length of day upon flowering and growth, try to get permission to use a greenhouse for experiments with asters, cosmos, and chrysanthemums, 2-222-23. Otherwise, conduct your experiments in the house, if you can.

Summary Statement

Plants will flower at different times during the growing season. Some burst into bloom when the days get short; some when the days get long. Growers of plants make use of this fact by using artificial light to make plants grow long before they flower.

Photo by Cornell University

This picture shows very clearly the effect of temperature on certain kinds of plants. At the left are four celery plants that were raised in a greenhouse where the temperature was kept at 60° F. The four celery plants at the right were raised in a greenhouse where the temperature was kept at 70° F. The plants at the left are the same age as the plants at the right, but because of the cooler temperature in which they grew they have formed seed stalks. The plants that lived in the warmer temperature have not done so. This illustration will show what a difference a hot summer may make to the truck farmer.

WHY *the* FLOWERS BLOOM WHEN THEY DO

Do You Know Why Daisies Come in June and Asters in the Autumn? Could You Make the Daisies Bloom at Christmas?

WHY do some plants blossom in the early spring, others in midsummer, and others in the autumn? We are so used to having violets come out in April or May, iris, clover, and daisies in June, and asters and cosmos in the autumn, that fairly few of us have troubled to wonder why they behave in this way or whether we could change their time of blooming. In the same way we are used to expecting late-planted lettuce, spinach, or radishes to go to seed instead of developing the edible leaves or roots that we get if we plant them early in the spring. When certain varieties suddenly behave differently, however—when whole fields of celery go to seed the first year instead of developing edible stalks, or when beets or cabbage develop flower stalks instead of the edible roots or leafy heads—then we realize that sometimes the habits of a plant can be changed. Celery, beets, and cabbages usually blossom the second year after coming up from the seed; that is, they usually behave as biennial plants. But once in a while growers suffer a considerable loss because these plants do not behave as has been expected.

Some celery growers noticed that in the years when they set the plants out into the field very early, or when there had been late frosts, many of the plants flowered and went to seed. This made them think that perhaps

freezing the young plants was what had made them blossom early. So they tried experiments to see what effect freezing would have on early flowering, but they found it had no effect at all. They did find, however, that if one lot of plants is grown in a cool greenhouse, at about 50° or 60° F., for two or three weeks, and another in a warm house, at from 70° to 80° F., for the same length of time, and if both lots are then planted in the garden, those that had been in the cool house would all go to seed early, while those from the warmer house would not go to seed. Many other kinds of treatment had little or no effect on the time of flowering, but keeping the plants for a time in the cooler house, or in a cold frame, practically always made them come into bloom before the normal flowering season.

Photo by Cornell University

These strange-looking plants are nothing but garden beets. Because they were grown in a greenhouse where the temperature never fell below 60° F., they did not produce seed stalks.

This explained why it was that in some years so many celery plants would go to seed. It also taught the growers how to keep their plants from doing so. They could keep the young plants in a warm greenhouse, put them outdoors only when the colder weather was gone, and so prevent early or premature flowering. It was not the occasional frosts that made plants go to seed, but the many days of cool weather that are likely to go along with frosts.

Making Cabbages Bloom to Order

These facts are of use to seedsmen, also, for now they know how to make the plants all go to seed the first year, and do not have to carry the plants over into the second year to get seed.

It has been found possible to control the blossoming of cabbages in much the same way as that of celery. In a cool house, cabbage plants can be made to develop a flower stalk instead of a hard, leafy head. On the other hand, if the plants are kept in a warm greenhouse all the time, they may form only leafy heads, one after the other, on the top of a stalk that gets longer and longer as each new head develops. The leaves of each old head drop off when the new head is formed. Such a plant was grown for three years in a warm greenhouse without blossoming. It had formed six heads in all, one above the other, on the top of the stem, which was growing longer with each succeeding head. The last one was on the top of a stem eight feet tall. At this time the plant was placed in a cool house, and then it developed flowers. In the meantime sister plants, raised from the same lot of seed, or slips taken from the same plant, were made to develop flower stalks whenever they were grown in a cool greenhouse, or when they were stored for two months in a cool room or cellar.

Some of our plants that blossom in the spring probably do so because the cool weather of the early spring or the autumn before has in some way made the flower buds develop. Another very important condition that affects the time of flowering of large numbers of plants is the length of the day. The days are longer than the nights in summer, but the nights are the longer in winter. Our longest days come in late June, and range from 12 hours near the Equator to 24 hours inside the Arctic Circle. In the Northern United States the longest days range from 15 to 16½ hours. The British Isles are farther north, and their longest days are from 17 to 19 hours long.

Not until about 1920 was it clearly recog-

nized that one of the most important factors controlling the time of flowering in many plants is the length of the day, or the "photoperiod" as it is called. But we now know, from careful experiments, that a number of plants will grow readily, but will never produce flowers, if the daily period of light is much more than 12½ to 13 hours long. Many autumn-blooming plants are in this class. That is, they will grow well during the summer, but they will not blossom until the days grow shorter in the autumn. Among such plants are asters, chrysanthemums, cosmos, and poinsettias, which blossom during the short days of the year, and late varieties of corn, soy beans, and lima beans. These plants can be made to blossom in midsummer if they are covered so that they receive no more than twelve hours of light a day. In other words, they must have twelve hours or more of darkness each day, for from two to four weeks, before they will blossom. Nor will covering during the middle of the day be effective, even though they receive a total of no more than eleven or twelve hours. The dark period must be continuous. By covering plants in the evening and removing the cover in the morning, it is possible to hasten the blossoming. The same kinds of plants grown in the greenhouse during the long nights of the winter months will blossom early. These plants that need short days and long nights to make them blossom are often called "short-day" plants.

Photo by Cornell University

At the right is a three-year-old cabbage plant that never flowered because it was kept in too warm a place. Instead, it produced a succession of six heads at the points numbered on the stalk. After the sixth head was formed, eight feet above the soil, the plant was put in a cool place, and flowered in a few months. The cabbage at the left sent up its long seed stalk as soon as the first head was moved to a cool place.

There is another class of plants, the "long-day" plants, that blossom only if they have long days and short nights. Many of the plants that blossom naturally during the long days of early summer belong to this group. Among these are iris, clover, spinach, lettuce, radish, and many other summer-blooming plants. When these plants are grown in the greenhouse during the short days of winter, they may grow slowly all winter but never blossom until the days get long. The same plants can be made to blossom in the winter, however, if the days are lengthened by the use of artificial light.

If artificial light is used to prolong daylight in the winter, "short-day" plants can be made to continue growth without flowering. The experiment was tried with late-blooming cosmos. The plants grew all winter with artificial light, and were then planted outdoors, where they grew all summer and finally blossomed when the days grew short in autumn. The cosmos had grown to be a giant plant fifteen feet high. Other plants from the same lot of seed were kept in a greenhouse receiving only daylight during the short winter days. These blossomed in less than two months, when they were only thirty inches high.

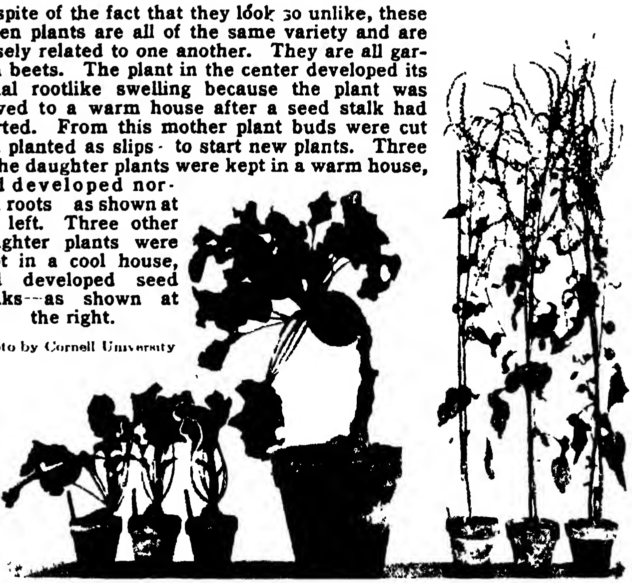
A similar experiment was tried with a common weed, the beggar's tick. The plants in the house with artificial light grew all winter with no sign of flowers, even though they reached a height of five feet. The plants receiving only the natural light during the short winter days developed tiny flower buds when they were only an inch or two high and had only two pairs of leaves. All this difference in time of flowering and size of plant was controlled by the length of the daylight. Yet there are several varieties of plant that are not greatly influenced by the length of

daylight. Early varieties of corn, cosmos, beans, and many other plants seem to be very little influenced by it.

Not only is the time of flowering in many plants controlled by the length of daylight, but the behavior of the plants in other ways is often greatly changed. Some varieties of potatoes will not produce the tubers we eat except during short days. The yam and the artichoke also produce more or larger tubers during short days. The scarlet runner bean will produce large, tuberous, storage roots if it is grown during short days, but normal, fibrous roots during the long days of summer. Some varieties of onion, on the other hand, will produce large storage bulbs only during long days. Some kinds of plants will branch more when the days are short. Some will form only a flat rosette of leaves when the days are short, but a long stem if the days are long. In some plants the development of autumn colors and the falling of the leaves is partly controlled by the shortening of the days.

There are many other interesting effects of the relative length of day and night on plant behavior. Some of these the botanists are just beginning to find out. In some cases the behavior is controlled partly by day length and partly by temperature. It has recently been found, for example, that beets will blossom only if the days are long, but that long days alone will not cause blossoming. The beet must also be exposed for a time to a rather low temperature. If exposed to moderately low temperatures and long daylight at the same time, it is likely to flower without forming any big storage root at all. If the temperature is high and the days are long, it will form the usual fleshy root, but will not blossom unless this storage root is kept for a time at a cool temperature. If stored in a warm room and planted again the next year, it will not blossom but is likely to make a second swelling much like the first root; this second storage organ will develop from the stem above the first root.

We seem to have a good deal more to find out yet about the ways in which temperature and length of day affect the behavior of many plants. Recent tests even seem to show that the length of daylight has a good deal to do with the behavior of many animals as well as, for instance, with the migration and nesting habits of the birds, who arrive in the North at the same time every year.



In spite of the fact that they look so unlike, these seven plants are all of the same variety and are closely related to one another. They are all garden beets. The plant in the center developed its aerial rootlike swelling because the plant was moved to a warm house after a seed stalk had started. From this mother plant buds were cut and planted as slips to start new plants. Three of the daughter plants were kept in a warm house, and developed normal roots as shown at the left. Three other daughter plants were kept in a cool house, and developed seed stalks—as shown at the right.

Photo by Cornell University

BOTANY

Reading Unit No. 38

HOW WE TRANSFORM OUR FLOWERS AND FRUITS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How important food plants and garden flowers were developed, 2–226

The meaning and value of "sports," 2–226-27

How the "American Beauty" rose was produced, 2–227

The origin of modern sweet peas, chrysanthemums, geraniums and tulips, 2–227-30

How plant grafts are made, 2–231

How we developed our pears, 2–232-33

Things to Think About

What kind of food should we eat if plants had never been improved by man?

How does the scientist change wild plants into new, useful types?

In what way are plant breeders important to the welfare of our country?

How do new plant varieties appear with man's aid?

How are new plant varieties made to last?

Picture Hunt

In what ways are modern ears of corn superior to those of the wild types? 2–226

How did we get our hundreds of varieties of tulip? 2–229

How can we grow seedless oranges without planting seeds? 2–230

How are different plants grafted together? 2–231

What insect friend has helped us to develop new plants? 2–232

Related Material

What plants were already domesticated by the Indians before the white man came? 7–123

What part do plants play in the life of mankind? 2–1

Of what use are flowers to plants? 2–101-3

How do insects cross-pollinate flowers? 2–107-9

Leisure-time Activities

PROJECT NO. 1: Using a cleft graft, make a rosebush bear several kinds of roses, 2–231.

PROJECT No. 2: Kill a bee after it has visited some flowers. Study its pollen baskets on the hind legs. Examine this pollen with a microscope, 2–107-9, 232.

Summary Statement

Mankind cannot leave the improvement of his food plants to nature. Instead, he speeds up the process by constantly breeding, selecting, and propagating the most desirable plants.

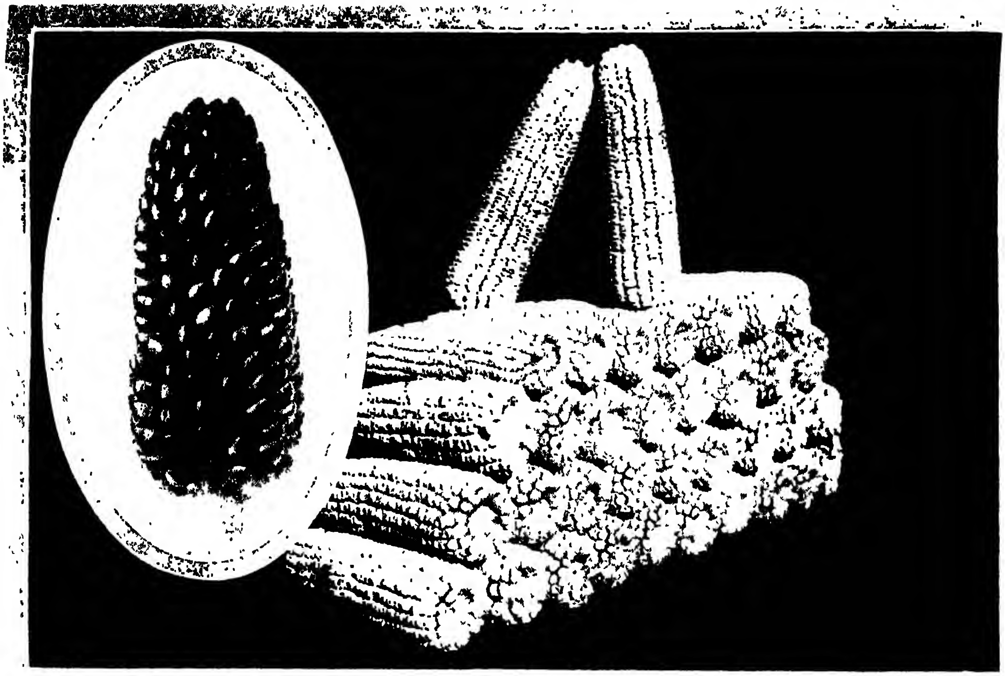


Photo by Iowa State College

The next time you set your teeth into an unusually succulent ear of corn, stop to think gratefully of the men who have worked hard to develop our cultivated corn from the wild maize plant with its small, irregular ears, a good deal like the ear shown in the oval above. Constant selection and careful crossing and breeding are the secret. Nor is corn by any means the only plant in which man has developed the qualities he desires—whether size of fruit, beauty of color, or suitability to some special climate. Lately seedsmen have improved certain strains by treating the plants with a poison called colchicine (kŏl'chĭ-sēn).

HOW WE TRANSFORM OUR FLOWERS *and* FRUITS

Compare Our Best Cultivated Apples, Roses, and Asters with the Wild Varieties. How Did We Get Our Fine Improved Varieties?

THERE once was a time when all the plants in the world were wild. Even when people first began to grow them in gardens, the flowers or fruits or seeds in the garden were very much like the wild ancestors in the fields and woods. As the years and centuries rolled by, however, the gardeners, by selecting and propagating those varieties that for some reason or other seemed more suitable, slowly developed strains that were more and more unlike the wild plants of the fields—larger, more brilliant, more fragrant, more productive, and more useful to man in all sorts of ways. And now our roses and chrysanthemums, our tulips and our dahlias, our apples, pears, cherries, and grapes, have been so changed that they hardly look at all like their wild ancestors. Sometimes it is even hard to know what their ancestors were, and sometimes the ancestors are so rare as to be difficult to find.

For hundreds of years the gardeners and plant breeders have been at work developing new varieties of flowers and fruits and vegetables, with the results that we see in all our gardens of to-day. The gardeners have used all the methods of selection and of crossing they could try, and they have always kept a sharp lookout for "sports"—that is, for those rare plants which for some curious reason are different from their ancestors. A single "sport" may sometimes be worth an immense

sum to growers because it may start a whole new variety of plant.

The result of all this patient work is seen in our thousands of different garden flowers, vegetables, and fruits. The full story of only the most important of these would fill all our volumes. But at least we can see where a few of our best-known cultivated plants came from and how they were developed. From their story we shall understand why growing and breeding flowers has become a pleasant hobby with many persons and the lifelong profession of a goodly number.

The best-known of our roses in this country is the one we call the American Beauty, but it is not at all American. Its history goes back to a time long before America was found, for its parents were French and their parents were part Chinese.

Long ago, in the days before much was known about China, there was a wild rose in that land with a single, brilliant red flower, and with no fragrance at all. This rose was brought from China to Europe by a famous Austrian botanist in 1768. It was called "Rosa chinensis," or the "China rose."

Photo by American Museum of Natural History

Wild roses, lovely as they are, are so different from the cultivated kind that we scarcely recognize them as the same flower. Yet it was from just such simple wild roses as these that the gardeners developed the great doubled flowers in our florist shops and rose gardens.

Where the "American Beauty" Came From

Far off in the Indian Ocean is the island of Reunion, which belongs to France and which was once called Bourbon (bōōr'bŭn). To a garden in that island some unknown person once took a China rose, along with many other kinds of roses. Among these was the "Rosa gallica," a common wild rose of Europe and Western Asia which had been grown in France since the days of the Romans.

This unknown rose lover in the island of Reunion is supposed to have crossed the China rose with the "Rosa gallica." About 1819 he sent the result of the crossing back to France under the name of "Bourbon rose." The new hybrid grew to be a great favorite with the French rose growers. It had "good blood" in it, for the China rose is also one of the distant parents of the Baby Rambler and of several other well-known roses.

In 1875, after the Bourbon rose had produced many other forms, it was taken in hand by a French rose lover. He did his best to produce a rose with larger flowers, and above all with a sweet scent. By crossing and selection he finally produced a gorgeous scarlet flower with a fine odor. Like most rose fanciers, he thought it would be a good idea to name the new rose after a lady, and he called it "Madame Ferdinand Jamin." That rose is our present "American Beauty." For in 1886 an American nursery firm brought the plant to this country, where it has long borne its present name. It has gone to every florist shop in America and has even been proposed as our national flower.

Two thousand years ago the Japanese knew and loved the chrysanthemum. They are supposed to have found it in China, which is still the home of a wild plant that is probably the ancestor of all our modern chrysanthemums, though it looks very unlike them now.

Until as late as 1696 the plant was still unknown in Europe, but about that year it was brought over from Japan to England in a ship of the East India Company. At that time the plant looked very little like our modern varieties. In fact, this first Japanese chrysanthemum was not much more impressive than a colored daisy.

But gardeners and plant breeders thought they saw a future for it. They began breeding it, and by 1789 they had improved it so

Photos by W. Atlee Burpee Co.

Amazing things can be accomplished with careful breeding of plants. Often the puny can be turned into the magnificent and the ugly into the beautiful and the useless into the valuable. For example the three blossoms above are all zinnias. Breeders have turned the woebegone little plant at the left into the chrysanthemum flowered zinnia in the center and finally into the giant at the right.

much that the flower was nearly three times the size of the original, and much "doubled." The doubling has gone on ever since, so that to-day we have chrysanthemum heads nearly a foot through.

The Many Forms of the Chrysanthemum

In the wild state, probably a great many years would have passed without producing a bloom of that kind. Man has taken only about two hundred years to do it. To-day, besides this huge flower, there are hundreds of other varieties of chrysanthemum, many of them hardy garden plants. So, starting with only a handful of wild plants that looked much like daisies, we have grown a vast variety of flowers, different in size and shape and color. The chrysanthemum shows better than most flowers what can be done by patient crossing and selection.

In 1699 Father Franciscus Cupani (kōō-pä'nē), a Sicilian priest who loved to wander over the mountains, found a pealike vine which he had never seen before. He noticed that it was unlike the ordinary garden pea because its blue and purple flowers had a sweet scent. He sent seeds to England, where the plant was at once called the sweet pea, because of its very pleasant fragrance.

These Sicilian peas were rather rare at first, and for a while the English gardeners could not get the plants to produce anything but the original blue and purple flowers. The gardeners tried every method they knew, but not until 1718 could they get a pure white bloom, and not until 1737 did they secure a pink and white variety.

Then the interest in developing new kinds of sweet peas lagged, and for a long time there was little change in the flowers. But just before our Civil War there appeared, still in England, the first yellow variety of sweet pea, though even with this there were only nine different forms known by 1860. At that time, however, sweet pea growers became busy. From the nine varieties scores of new ones were developed, mostly as the result of hundreds of crosses.

When Sweet Peas Were Brought to America

No one seems to know why this beautiful flower should have been so late in reaching America. Perhaps it was because its development from its wild ancestor had been so slow. Except as a rare freak, it did not come here until 1886. But about that time all the English varieties were imported. Since then the American growers have produced hun-

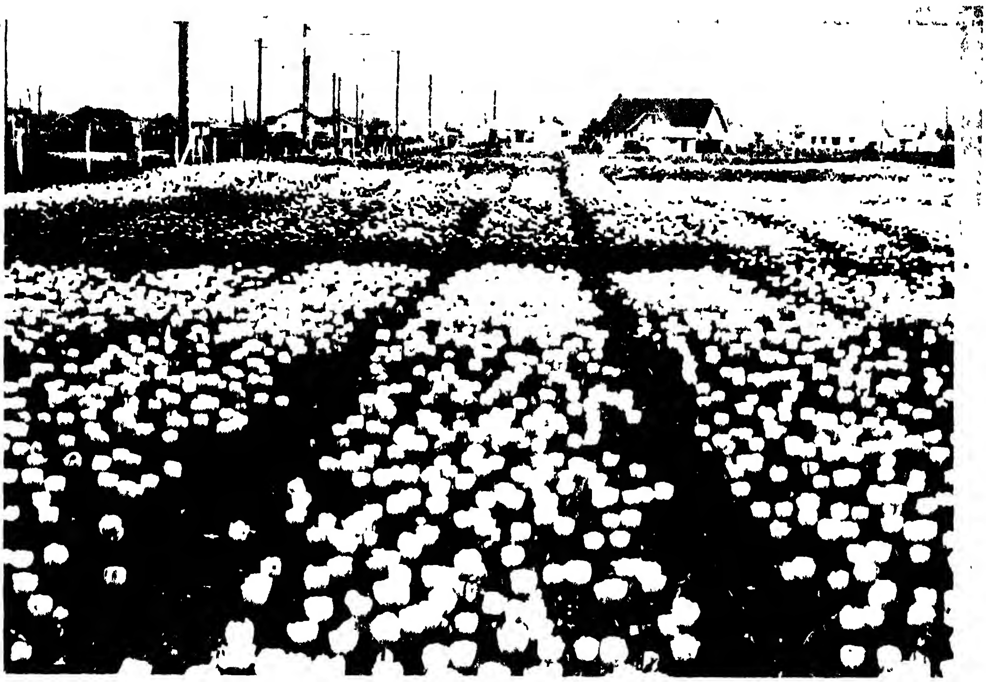


Photo by Bellingha , Wash , C of C

Acres and acres of tulips, in hundreds of sizes, shapes, and colors! Is it not amazing to consider that they have all been developed by selection and breeding from a single wild tulip ancestor?

dreds of varieties; and we can now have sweet peas in nearly every color, even almost black, and with all sorts of stripes and bandings—all made from that single wild flower from the island of Sicily.

Where Geraniums Came From

When in 1664 the Dutch surrendered New York to the English, Holland began to look for new regions to colonize. She owned Cape Colony, or what we call South Africa, but no Dutchmen wanted to go there. So in 1685 Holland began sending shiploads of orphan Dutch girls there to help in colonizing the Cape. One of the ships brought back to Europe the very first garden geranium ever seen there.

At first it was not very different from the common cranesbill which grows naturally in Europe, nor very unlike the common wild geranium of North America. And it did not look in the least like the potted geraniums in our windows, nor like the million others used every year for decoration.

Gardeners in Holland and England were astonished when each returning ship brought other and different geraniums from South Africa. And years later all the scientific world was surprised to find that in South Africa there are over two hundred species of "Pelargonium" (pĕl′är-gō′nĭ-ŭm), which is the Latin name for all our garden geraniums.

Some of these South African wild flowers were vastly improved by European gardeners. We now have the ivy geranium, the oak-leaved geranium, the nutmeg geranium, and the fish geranium, besides the one we all know best. The history of this commonest of all geraniums is practically lost, because no one kept a record of its ancestors.

The Ancestor of Modern Tulips

And those ancestors are legion. Most of the new species from the Cape were grown and used in crossing with older varieties. Soon the number of hybrids was up in the hundreds. Every shade of white, pink, and red was finally developed, but no blue flower has ever appeared. The English were also very much surprised to find that in the warm

and moist parts of the south of England the plants would grow up to the second-story windows!

But in spite of this ability to grow, most of our modern geraniums are used as bedding or pot plants. Aside from the improvement in color, there has been a great increase in the size of the blooms since 1714, when the geranium had already become a common bedding plant in Europe.

Hundreds of years before the crusades the Turks used to call one of their wild flowers "tulbend," which was also their word for a turban. The flower looked a good deal like a turban turned upside down, and that flower was the ancestor of all our modern tulips. Outside Turkey it was found, and still grows as a wild plant, in parts of Southwestern Asia.

Photo by American Museum of Natural History

Do you see anything odd about this orange? It has no seeds! Navel oranges never have seeds. That means of course that every new tree has to be started, not from a seed, but from a slip cut from an older tree. All our navel orange trees have been derived in this way from one ancestral tree which developed the strange habit of setting no seed. The same thing is true of any seedless plant.

Just when the first wild tulip bulb was brought to Western Europe is a bit uncertain. Perhaps it came with the traffic that followed the last crusade. But it was long after that (1554) before tulips were found growing in an Austrian garden. By 1591 a famous French botanist named Clusius (klū′-sĭ-ŭs) had learned how to propagate the new flower and had largely increased its size. It had already been brought into England and Holland, and in the latter country, from 1634 to 1638, there was an outbreak of an entirely new craze among men—"tulipomania."

For four years Holland went tulip mad. Hundreds of varieties were developed. Whole villages and corporations were speculating in tulip bulbs, just as we speculate to-day in wheat and cotton. "Corners" were forced on especially fine or rare varieties. At the peak of the excitement a single bulb was carried up to a price of thirteen thousand florins—about $10,000 in our money now. In 1638 the craze ended in a crash of the bulb market, and thousands of Hollanders were financially ruined.

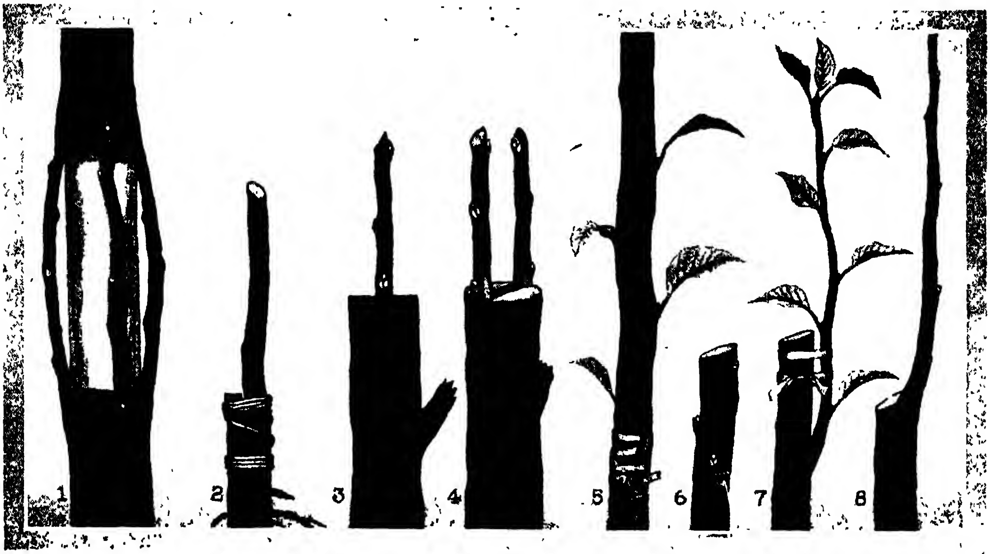
But to this day Holland remains the chief country in the world for tulips. Since tulipomania died out the Dutch have created hundreds of standard varieties, separated into several types. Two of the best known are the "Darwin" and the "May-flowering" tulips. The Darwins are tall, large-flowered tulips with incurving petals. The May-flowering plants bear shorter, earlier tulips with erect petals.

In these and other groups we find every color in the rainbow, every kind of shading and marking. Even black tulips are known. All of them have come from that single wild flower that the Turks called "tulbend."

All over Europe and the temperate parts of Asia there has always been a large genus of the beautiful flowers which we call pinks and which the botanists call "Dianthus" (dī-ăn′thŭs). One of them was called "Dianthus caryophyllatus," because it smelled a little like cloves, and "caryophyllus" (kăr′ĭ-ō-fĭl′ŭs) was an old name for the clove. That particular pink is the clove carnation, and the ancestor of all our modern carnations.

The plant has been grown for ornament for two thousand years. The Romans knew it well, and they first gave it the name "carnatio," which is Latin for "fleshy." At first it was flesh-colored; and indeed for hundreds of years, in spite of steady culture and great efforts, only pink or reddish carnations were known.

But finally, about 1700, the gardeners split



Many important garden and orchard plants do not come true to seed, and the only way to make more of them is to propagate them vegetatively. One way of doing this is to bud or graft a good variety on the stem of another that has good roots but poor quality of flowers or fruits. The buds or twigs of the good variety are called cions (sī'ŏn), and the plant which furnishes the roots is called the stock. 1, above, shows a bridge graft. When a tree is girdled by mice or rabbits the roots will die because the part of the bark which carries food to the roots has been destroyed. By the bridge graft a new layer of bark running across the girdle serves to connect the two parts again. 2 is a whip graft. 3 and 4 are cleft grafts. In another method called budding (5, 6, 7, 8), only a small slit—usually T-shaped—is cut in the bark of the stock, and a single bud with a bit of attached bark and cambium is slipped under the bark and bound in place. After the tissues have knit, the top of the stock is cut off and the cion shoot develops. In all kinds of grafting it is important that the cambium of the cion be in close contact with the cambium of the stock, so that the two may unite. Usually the tissues are bound tightly together and the open wounds covered with a moisture-proof wax to prevent drying. You will often find examples of grafting in the stems of fine rose bushes.

the colors, and began to produce true white carnations, as also pure red ones. These were still comparatively simple flowers, however, and were never doubled, as are all our modern carnations. They continued to have the clove odor.

How Carnations Were Developed

For 140 years gardeners and breeders kept working over carnations. Not until 1840 did the French at last develop a flower which was at least a little like the one we see to-day in the florist's window.

After still more work had been done on them, the varieties were brought over to America, where they were much improved about the time of the Civil War. In our day the finest varieties are all American, and the European florists now use the American kinds more than their own. Next to the rose, the carnation has come to be the most widely cultivated flower in the world.

We have made our carnations so big and their stems so long that they have to be supported by wire guards in the acres of greenhouses needed to grow them. Some carnations have their petals edged with a different color, and even variegated flowers are known. For eighteen centuries the old Roman "carnatio" still remained a single flower. But the genius of the French and American growers, within a hundred years, developed the modern carnation. That is almost the fastest work on record in plant breeding—but not quite the fastest.

A Flower That Developed Quills

In the uplands of Mexico there is a small genus of herbs with daisylike, colored flowers. They are dahlias, and are closely related to the common sticktight and to the cosmos. English gardeners paid almost no attention to them when the first plants were sent to Europe in 1789.

But in a little while the English and French gardeners grew very much interested, for the

new Mexican flowers began doubling almost at once. They could be easily crossed, and just as easily raised from seed as from tubers. It did not take long to produce hundreds of varieties, and by 1840 there were over a thousand. Scarcely a dozen of those old flowers are known to-day, and most people do not care much even for the ones they do know. The flowers grew so very double, and so large and coarse, that they looked almost like colored cabbages or even like artificial flowers.

So people soon lost interest in the huge double blossoms, and dahlias would be little seen to-day if something quite new had not cropped up in the dahlia family. An entirely new strain of dahlias was suddenly developed in Holland in 1879. In that year a tuber of a new species of wild dahlia was brought from the flower's home in Mexico.

Photo by Cornelia Clarke

Here is a little member of animal society that has played an important part in developing new varieties of flowers and fruit by carrying pollen from one sort of flower to another and thus making hybrids.

Almost at once the newcomer began to have *quilled* flowers, and from it there was developed that whole new race of plants we now call the "cactus dahlias." They are far more beautiful than the old kind—more open, more fluffy, and more like the modern chrysanthemum. To-day there are hundreds of varieties of these cactus dahlias, nearly all of them having been developed in France and in America since 1900.

How Fruits Are Perfected

Just as there has been much breeding of our cultivated flowers to bring them to their present state of perfection, so has a great deal been done in perfecting the fruits and vegetables. We are constantly being introduced to new varieties, each of which has its own particular features.

We know as much perhaps of the history of the pear as we do of any of our other fruits. When we sit at our tables and eat a large, juicy pear, little do we think of the many years it has taken to produce such a delicious fruit. As we go through a pear orchard and see hardy trees bearing large quantities of fruit, we may be sure that the plants look very different from their original parents.

Most of the common varieties of pear in America and Europe to-day have come largely from two original species. One of these is the pear we often read of in history. It grows wild over the large part of temperate Europe and Western Asia. In ancient times, the fruit of this pear seems to have been of very poor quality and flavor. Through the constant efforts of the breeders in Europe, however, many desirable varieties of it were selected. And some of these varieties were brought to America by the early colonists.

But there is another species of pear growing wild in Mongolia and Manchuria. This species has played an important part in the development of some of our present varieties. It had been cultivated in China for centuries before it was carried to other parts of the world. In Europe and America the people did not like the fruit of this pear because it was hard, with gritty flesh and a poor flavor.

But some of the pear growers thought that perhaps it had certain good qualities, even thought it had some undesirable ones. So breeders in Europe and America began to cross the European species with the Chinese one. It was not long before there were many new varieties of pear. Though many of these

varieties have produced fruit of only a fair quality, their vigorous growth and general resistance to disease have made them desirable. The Kieffer pear, originating near Philadelphia, the Garber, originating in Pennsylvania, and the Le Conte, were among the first to be developed in the United States. Still further breeding has taken place in recent years, so that we now have numerous hybrids which are grown for their special qualities.

The Ancient Culture of Cabbages

Our breeding of vegetables, such as squash, pumpkins, lettuce, and celery, has progressed along the same lines as the breeding of our flowers and fruits. From the original forms, hybrids have evolved with favorable features. The culture of our common cabbage, for instance, seems to precede any reliable historical record. Writers before the days of the Greeks tell us of the variations in growth and character of this plant. These probably were due to the cultivation and selection of cabbage plants for many generations. It is difficult to believe that our cabbage plant of to-day originated from a scrawny, starved-looking plant. But the historians tell us that it is so.

It is hard to say just how much farther the breeding of plants can be carried. Certainly many of the cultivated plants of to-day look very different from those of fifty years ago. Perhaps we may expect a similar change in the next fifty years.

Plants of Hybrid Origin

So many common garden flowers have come from crossing that the early history of many of them is hard to trace. It is so easy to go into the garden and transfer pollen from one flower to another that the thing has been done millions of times. Many of the people who have done it have then forgotten which of their flowers they had crossed. When the new plants grew up looking different from their parents, they were just put down in the books as of "hybrid origin"—which means that they resulted from crossing.

But in recent years we have kept better records, and the parentage of many of our finest cultivated flowers is fully known. This is often important in telling us where they will grow best whether in California, for instance, or in Maine. For that depends partly on the country where their wild ancestors were found.

No matter how many varieties there may be of a single flower—and there are over a thousand kinds of tulip, for instance they have all come from one wild ancestor, or at most from very few. And they never shake off all of the habits and needs of their wild ancestors. That is why our tulips "rest" for some months, in spite of the hundreds of generations of them that have lived in regions very different from their original Turkish home.

Through the years we have enormously improved the shape and color of our flowers, but we find it harder to alter some of the habits that have come down to them.

Flowers That Originated in America

Those that are European in origin have been known in cultivation for many centuries. But as we found in the case of the geranium and chrysanthemum, those from China or South Africa are much more recent.

Before Columbus arrived in the West Indies, none of the plants in the following list had ever been heard of in European gardens. Like the dahlia, they are natives of the New World. From America some were taken over to Europe, and after years of breeding, both in the Old and New World, we have the forms we know to-day.

Begonia	Mostly tropical America
Canna	Mostly tropical America
Cosmos	Mexico
Four-o'clock	Tropical America
Fuchsia	Mostly tropical America
Marigold	Mexico
Nasturtium	Peru
Phlox	Texas
Salvia	Mexico
Zinnia	Mexico

The potato, Indian corn, tobacco, and certain varieties of grape are the more important agricultural plants that originated in the Americas.

Reading Unit No. 39

HOW THE MAPLE TREE MAKES SUGAR

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How the tree gets its sugar, 2–235-36

Why "girdling" a tree is fatal to it, 2–236

When does sap flow in a tree? 2–236-37

Why maple sugar has a maple flavor, 2-237

Why the maple tree needs sugar, 2–237-38

Does removing maple sap harm the tree? 2–238

Things to Think About

Why does a tree need leaves?

Where is a tree's food stored?

How does weather affect the maple-sugar industry?

How does the sap move in a tree?

How does the maple tree use its sugar?

Picture Hunt

What is done with maple sap after it is collected? 2–235

How is maple sap removed from the tree? 2–236

Related Material

How do green plants make their own food? 2–40-46

How do we get sugar from other plants? 9–113-16, 126-27

How can you recognize a sugar-maple tree by its leaf? 2–24

Leisure-time Activities

PROJECT NO. 1: Place a drop of iodine on starch. A blue-black color should appear. Apply iodine to a slice of bread, a cracked kernel of corn, a rock, a piece of fish, a slice of a twig, a slice of potato, a sliced tulip bulb, etc. Which ones have starch? How did starch get there? 2–236

PROJECT NO. 2: Learn to make maple-sugar candy, 14–85.

Summary Statement

Maple trees make sugar in the summer and store it in the trunk as starch. This starch is changed to sugar in the early spring when the sap flows. A hole in the trunk is made and the sap then flows through a tap into a bucket.

Photo by Vermont State Dept. of Agriculture

Such snowy scenes as this are common in Vermont and other northerly parts of New England in early spring. While the snow still lies on the ground the sugar man taps his sugar-maple trees and sets a bucket under each to catch the sap. Then when the buckets are full he goes the rounds again, as here, emptying them into a great tub on his sledge. When the sap is all gathered or the tub is almost full, he will turn back to his boiling house to boil the sap slowly until it concentrates to syrup or even to sugar.

HOW *the* MAPLE TREE MAKES SUGAR

Does It Hurt the Tree to Steal Its Sap? And What Becomes of the Sap if We Do Not Steal It?

ALL of us know the taste of maple syrup or maple sugar, and some of us have had the fun of actually visiting a maple grove, or "sugar bush," where we may have sampled the syrup taken directly from the evaporating pans, or have tasted the faintly sweet, fresh sap from the pails attached to the trees. Most of us know that late winter is the season when most of the sap is collected from the maple trees.

Although we like maple sugar and in a general way know how it is obtained from the tree, many of us have not thought much about where the tree gets the sugar, how the sugar gets into the trunk, why the sap flows chiefly in late winter or early spring and little or not at all at other seasons, why the flow is good on some days and poor on others, or what would finally become of it in the tree if we did not draw it off. Perhaps a dozen other questions may arise when we once begin to think about the matter.

Where does the tree get the sugar in the first place? There is a widespread popular notion that plants get most of their food directly from the soil, where they find it dissolved in the soil water. This, however, is a mistake. It is true that plants require water and certain small amounts of salts. But the food requirements of plants are very much the same as those of animals. Both plants and animals require water, small amounts of inorganic salts, and large quantities of organic foods, especially sugars, proteins, and fats.

From the standpoint of the amounts used, the carbohydrates, or sugar and sugarlike substances, are the most important foods of both plants and animals. One of the chief differences between a plant, like the sugar

maple, and an animal is that the maple has special organs, the green leaves, which are capable of making sugar when they are exposed to sunlight. The raw materials out of which the sugar is made are carbon dioxide gas, which comes from the air, and water, which comes from the soil. In nature it is only the green parts that can make this food, and they can do so only when exposed to light under proper conditions. All other parts of a plant—the roots, trunk, branches, and fruit—are dependent upon the leaves for their food. Without this food they could not live and grow, but would die.

The food that is made in the leaves is carried out from them mostly in the form of sugar. The tissues which carry this sugar are located in the inner bark, or phloëm (flō'ĕm) region, and it is through this inner bark that the sugars are carried to all other parts of the plant, the branches, trunk, roots, and fruits. If this layer of the bark is completely cut at any point on a stem or trunk- in other words, if the stem is "ringed" or "girdled"—then the food cannot get back to the trunk or roots below the ring. These parts are then starved; their growth ceases and they eventually die. Immediately above the girdle, however, the food accumulates in larger quantities, and this accumulation often causes considerable extra growth in that region.

If you should cut a twig or root of the tree and test the cut tissues for starch, by applying a drop of iodine solution, you would find them filled with starch, as shown by the blue or black color caused by the iodine. A drop of iodine on a slice of potato will show the same reaction. The sugar that came from the leaves during the summer is mostly stored as starch in the tissues of the stems or roots. In the young twigs some of it is in the bark region, some in the pith, and some in the living ray cells that run radially inward from the bark toward the center. In the older part of the branch or trunk the starch will be abundant principally in the ray tissues. It is these ray tissues, by the way, that give the beautiful grain effect of quarter-sawed lumber. The tree is entirely dependent upon this stored food for its growth early in the spring.

Photo by Vermont State Dept. of Agriculture

This sugar man is in the act of tapping a tree. He bores a hole in the trunk a little way above the ground, inserts a tap, and hangs a bucket below to catch the dripping sap.

The exact cause of the early spring sap flow is not known. The best flow usually occurs on a warm day immediately following a night of freezing temperature. There must also be a good supply of water in the soil. For some reason, under these conditions some of the stored starch is digested to sugar, and the living cells lose some of the sugar into the water-conducting tubes where the pressures are developed. Possibly the process is similar to the sweetening of white potatoes which takes place when they are chilled. If the weather stays warm for several days the flow will become slow or will stop altogether. Under these conditions the sugar is changed back to starch or is used by the living cells.

In order to obtain the sap a tap hole is bored into the wood to a depth of two to three inches. The sap, which is under pressure in the water-conducting tubes, will then flow from this wound. Many people have the idea that this sap is flowing up the stem toward the twigs, but this is a mistake.

As many of you know, the best sap flow in the maple is obtained early in the spring before the buds break open. At this time of year there is probably little or no actual flow in the normal, uninjured tree. There is an abundance of sap in the water-conducting tubes, and this may be under pressures as high as fifteen or more pounds per square inch. When a hole is cut into the trunk, the sap, which is under pressure, flows out through the hole. But this does not prove that it was moving up before the hole was cut. It is even possible that some of the sap was actually flowing toward the roots. It has been found, for example, that if a maple is cut down at the season of best sap flow, little or no sap comes from the stump or roots, but a good deal flows down from the trunk above. In fact, there is likely to be enough suction in the stump to cause water to be absorbed if water is poured on the stump. Daily freezing and thawing result in changes from suction to pressure, and these changes seem most effective in causing a sap flow through the tap holes.

How Sap Flows in a Maple Tree

Later in the season, and especially when the buds begin to swell, considerable water may come from the roots; but in the maple this seems to have very little sugar in it and is of little use to the sugar maker. So far as the tree is concerned, it is in the summer and not in the early spring that the greatest amount of water actually flows through the trunk and evaporates from the leaves. On a hot day in summer, the leaves may evaporate water so rapidly that as much as a gallon a minute will pass through the trunk. If the tree is tapped at this time, however, no water will flow out. In fact, if water is applied to the hole it may be rapidly absorbed into the tree. You can see from this that the common notion that sap moves up in the spring and down in the autumn is a mistaken one. Though sap will flow from a tap hole early in the spring, very little water actually moves up at this time. On the other hand, a great deal of water moves up and is evaporated from the leaves all summer long. Throughout most of the summer, also, sugar is being made in the leaves, and moving down into the trunk and roots; and this downward movement does not take place merely in the autumn.

A number of different kinds of trees show this spring sap flow. But many other kinds do not. Most of the maples show it, but the true sugar, or hard, maple seems to produce the most sap and a better quality of sugar. Other plants, such as the hickory and butternut, the birch and sometimes even the grape, have a sweet sap. The grape sap, however, is usually very weak.

Why Maple Sugar Has a Maple Flavor

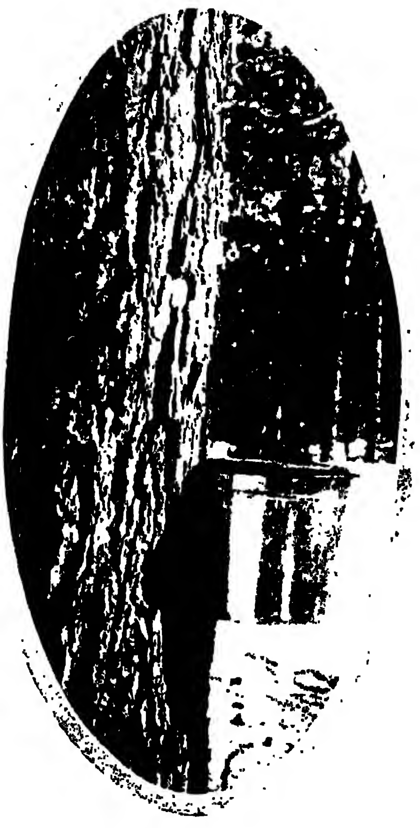
The principal sugar in the maple sap is the same as the ordinary sugar that comes from the sugar cane or sugar beet. The sweetness of maple syrup is due to this sugar. The peculiar maple flavor that we like so much is caused by small quantities of impurities that come from the tree and are not present in sugar cane or the sugar beet. The sugar in the sap of the birch is not so sweet and is chiefly glucose (gloo͞'kōs), the same sugar that we find in corn syrup. The amount of sugar in the sap is not very great—usually only about two to five per cent of the weight. For this reason the excess water has to be evaporated off to make the syrup or sugar that we use. Five quarts or about ten pounds of sap a day may be considered a fair average run from a tree. This may keep up for about ten days, yielding a total of about three pounds of sugar per tree.

How the Maple Tree Uses Its Sugar

In the normal course of affairs, the starch stored in the various tissues is gradually digested to sugar, and eventually moves to those parts of the tree that use it in their growth. Much of the sugar moves to the roots, which begin growth early in the season, probably long before any other parts grow. Part of the sugar is used in developing new shoots and new leaves, and part is used in making new layers of wood and bark on the branches, trunk, and roots. If there were no food stored in the tree when it loses its leaves in the autumn, the tree could not begin growth again in the spring; for food is necessary for growth and, as you remember, this kind of food is not taken from the soil.

After the new leaves come out they immediately begin to make more food, which may be used for continued growth or later may be stored for next season's growth. Sometimes there is enough food stored to develop a second crop of leaves if the first crop is destroyed by insects or in some other way; but often, especially in those trees, such as pines, that do not store much food, the tree will die if the leaves are removed soon after they are first formed and before they have had time to store a new supply of food.

You may wonder whether robbing the tree of some of its stored sugar is going to hurt the tree. The amount that will flow from the tap hole is only a small fraction of the total amount in the tree, probably rarely more than one-twentieth, and there seems to be little or no danger on this account. Cutting off several branches from a tree, and thus reducing the number of leaves that make the sugar, may reduce the supply of the tree more than drawing off some of the sap. Shading or crowding may have a still more harmful effect, since the leaves must be exposed to light in order to make sugar. The larger the leaf surface and the better its exposure to light, the greater will be the manufacture and storage of sugar. Then the tree, when tapped the next spring, will usually give a better flow of sugar than will a tree that has had less leaf surface. Partial loss of leaves by attack from insects, or by fungi that form leaf spots or kill parts of the leaves, is likely to be much more harmful than taking what little sap will flow from a tap hole.



Reading Unit
No. 40

THE TRAGEDY OF THE AMERICAN FORESTS

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Why our trees must be saved, 2–241
How the Forest Service works for us, 2–242
How forests are kept healthy and growing, 2–242-44
What goes on in a forest nursery, 2–245-46
The problem of forest fires, 2–246-47
How we fight forest fires, 2–247

Things to Think About

What is the program of the Forest Service?
How does the Forest Service make a forest endure?
Why are evergreens likely to catch fire in dry seasons?
Why are burnt areas hard to replant?
How are forest fires stopped by man?

Picture Hunt

How are forest fires detected? 2–241
How can you prevent forest fires? 2–242
What is a tree nursery? 2–243
How did the C.C.C. help our forests? 2–243
What is a fire line? 2–244-46
Why must we prevent forest fires? 2–240

Related Material

For what great work is Theodore Roosevelt remembered? 7–309
How large are some forest trees? 2–253
How do we get wood from forests? 9–245-58

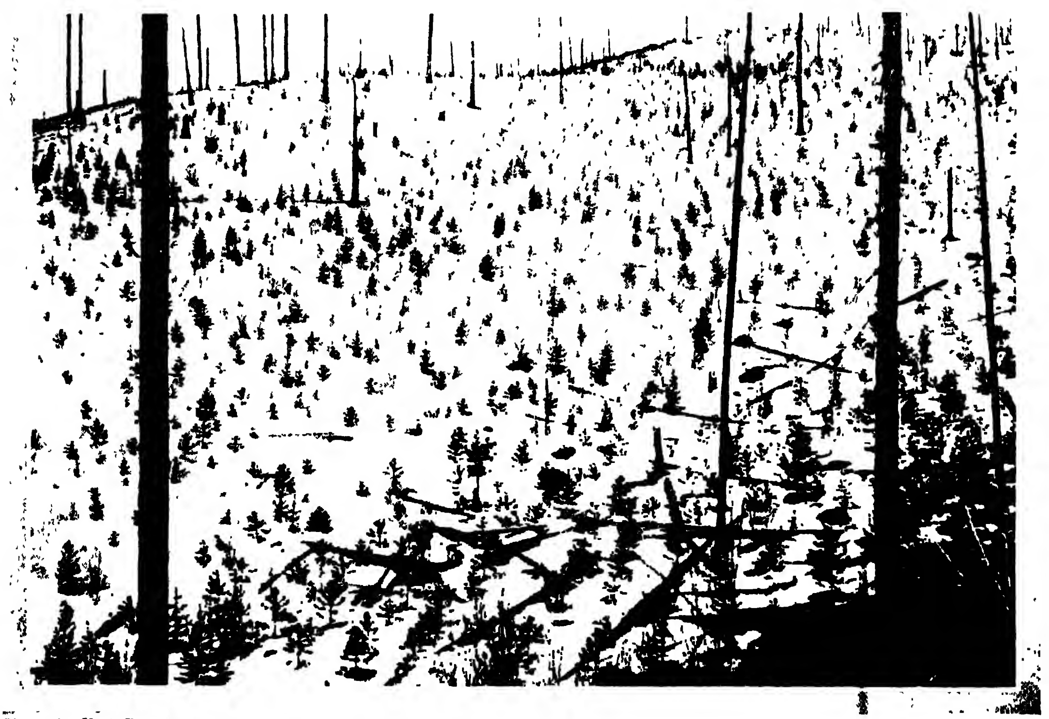
Leisure-time Activities

PROJECT NO. 1: Visit a government nursery to learn how our forests are made to endure.
PROJECT NO. 2: Ask your congressman to send you literature on the work of the Forest Service.

Summary Statement

Our country is trying very hard to save the forests, which in the past were ruthlessly destroyed and not replaced. In this work of conservation, the Forest Service has had great success.

Surely there are few sights more depressing than a burned-over forest. Too often in the western mountains one comes even yet upon this desolation. Sometimes whole companies of skeleton trees have weathered to a gleaming white—"ghost forests," we call them. Too often, too, there is the tang of wood smoke in the air, and a heavy pall of smoky haze tells too clearly that more ghost forests are in the making.



Photos by U. S. Forest Service

The trees that make our greatest forests are not swift in growth. These little pines, for example, have been growing for eleven years, and you can see that they are still a long way from being "tall timber." That is why we have to plan so far ahead in reforestation work, thinking in decades rather than years. It is also one reason why we should be more careful than ever not to start fires by our carelessness.

Photo by U. S. Forest Service

This was only a very tiny fire at first, started perhaps by a stray spark from a camp fire, or a cigarette someone forgot to crush out. With the help of a northeast wind it grew in a few minutes into the terrifying blaze you see here. Before it was brought under control it burned over hundreds of acres. Young saplings fell into ashes and countless majestic trees like these became gaunt, charred ruins.

The TRAGEDY *of the* AMERICAN FORESTS

How We Have Wasted Our Millions of Fine Trees, and What We Are Doing Now to Make Up for Our Vast Losses

WHEN Theodore Roosevelt became president of the United States, we were losing trees by cutting or by forest fires ten times as fast as they could be replanted, and perhaps a hundred times as fast as the remaining trees would grow. Roosevelt saw that we were wasting one of our greatest national treasures, and that we had been wasting it ever since the first white man planted his foot in Virginia. Our grandfathers and their great-grandfathers all thought that America was so big and its trees so plentiful that they could cut as many as they pleased. Even an occasional fire that burned up a few square miles of timber did not worry them very much.

President Roosevelt knew better. He knew that a part of China, four thousand years ago, had done almost exactly what we had been doing in the first three hundred years of our history. That part of China is now almost a desert. There are no trees in it. The mountains that were once covered with forests are now all cut into terraces; and to get things to grow on the terraces, the patient Chinese wearily carry soil up the mountain side to them— the very soil that was once washed down from the mountain as soon as there were no more trees with roots to hold it there.

No one wanted that kind of desolation to come to America, and Roosevelt set about finding people who could tell him how to avoid it. From his suggestion and the work that was then done big things have come. To-day, even after many years of splendid

effort, we are still cutting down trees faster than we can replace them. But the work of protecting and replacing them goes steadily on. No part of the government service has done more for the future of America.

For years before Roosevelt's time there had been at Washington a small bureau known as the Forest Service. It was badly mixed up in politics, and scarcely fit to cope with the huge task which the President knew must be done if America was to be saved from a catastrophe like the Chinese one.

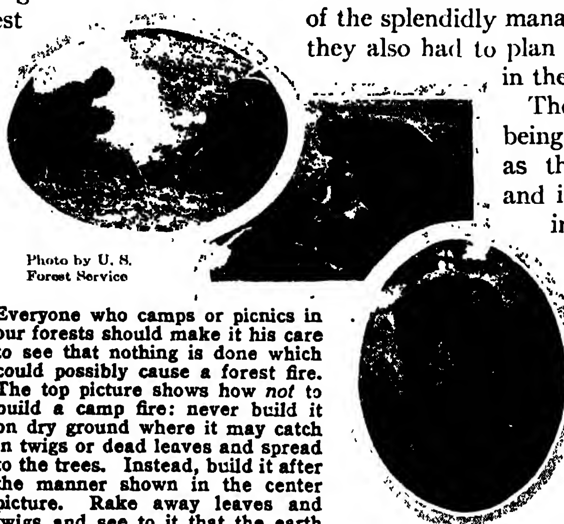


Photo by U. S. Forest Service

Everyone who camps or picnics in our forests should make it his care to see that nothing is done which could possibly cause a forest fire. The top picture shows how *not* to build a camp fire: never build it on dry ground where it may catch in twigs or dead leaves and spread to the trees. Instead, build it after the manner shown in the center picture. Rake away leaves and twigs and see to it that the earth around the fire is moist. Then, when you are through with the fire, put it completely out, and cover the ashes with dampened earth—as the camper in the third picture is doing.

He completely changed the Forest Service and greatly increased its scope. When the experts in the service began work they saw that three things must be done. One was that the government must buy or get control of as much forest land as possible. How well it has done this you can see from a map of the national forests to-day. These forests in the United States occupy an area that is larger than the whole of France.

How Forest Fires Start

The second thing was to prevent forest fires. A few of these are started naturally by lightning, but by far the greater number are caused by the ignorance or carelessness of visitors or lumbermen. We shall see presently what has been done to stop the fires.

The third thing was to replant the trees as fast as possible. This may sound easy enough, but in a moment we shall see that it has been done only after long study and an immense amount of labor on the part of the Forest Service.

The men in this service, scientists and forest rangers and fire wardens, are all working together to see that the almost incredible demands for lumber in America may be met, but without risk of losing all our forests of the future. The Forest Service knew about the municipal forests in Germany and Switzerland, where cutting has been equaled by replanting for a thousand years. In planning a task hundreds of times greater than that of the splendidly managed European forests, they also had to plan for hundreds of years in the future.

Their plan, still far from being so perfectly developed as the German one, was and is to make our forests into tree crops. No prudent farmer harvests a crop without preparing to plant seed for another one. But that is something we had never done with our forest crop.

It was soon found to be nearly useless to replant some of the forests that had been cut away or burned over. Reforestation could be accomplished in much better ways by working *with* Nature rather than waiting too long and having to fight *against* her.

Young forest trees, especially the evergreens, will be killed if fire burns through the litter in which they are growing; so the men in the service started a campaign against forest fires. Then they found that with proper cutting a forest would yield a good supply of timber but still allow for natural reseeding.

Let us go to one of the great National Forests in the West and see how the foresters there are working in league with Nature.

We get off the train at a tiny station in Oregon. On the bulletin board of the station is a poster that reads about like this:

> On Tuesday, October 17, 19—, at noon, the undersigned will receive bids for the sale of
>
> 600,000 board feet Douglas fir
> 40,000 board feet western red spruce

Photo by California Redwood Ass'n

These wide acres are planted to young redwood trees, for this is a redwood forest nursery in California. When they are old enough, the seedlings will be set out to replace old redwoods which have been cut or burned down. Many other kinds of forest trees, of course, are grown in our nurseries, also.

Photo by U. S. Forest Service

Here are men planting some of the nursery seedlings; but this is in the St. Joe National Forest, Idaho, and the trees would be fir rather than redwood. Clearly, this mountain side has been burned over, as the gaunt trunks of the old trees mournfully testify; reforestation is made more difficult by such a situation. This was the sort of work done by great numbers of the Civilian Conservation Corps.

Photo by U S Forest Service

These fire fighters are laying a hose from a firetruck to the fire in an attempt to get a head start on what could become a raging furnace in a California forest. Notice the tank they use in the operation. Mechanized units, helicopters, and even paratroopers equipped with smoke masks have a part in the war on forest fires.

250,000 board feet lodgepole pine
80,000 board feet western cedar

All timber to be cut and removed as directed.

U. S. Forest Supervisor.

This means that the Forest Service, after long study, is satisfied that trees of these species and in these amounts can safely be taken out of the particular forest at hand. But note that the forester says that the trees are to be "cut and removed as directed."

Why Big Trees May Be Cut Down

He will see that no part of the forest is left bare of trees. He and his men will go along with the lumberman and tell them which trees to cut and which to leave. We may be surprised to see how many of the biggest of the magnificent evergreens he marks for cutting. But there is sense and judgment and a world of forest knowledge in his choice.

In cutting the very biggest trees, which might fall in a few years anyway, he is really taking *fewer* trees from the forest. Most important of all, he leaves plenty of "seed trees." These are vigorous young trees, or even old ones, so spaced in the forest that their annual crop of seeds will be more than ample to fill in all the places left open by the cutting.

This is the best and most permanent type of reforestation. The government gets the highest price for the timber. The forest is self-perpetuating. In a few years there will be trees of every age in such a forest, and this will insure a regular supply for the future.

In many parts of America such perfect reforestation cannot be practiced, for we need a fine and very large old forest to make such a scheme work. Much of the National Forest land is not in such good condition, because in such places the government began its management nearly a hundred years too late.

Photo by U. S. Forest Service

This is Castle Peak Lookout, in Holy Cross National Forest, Colorado. It is certainly well named, for it looks indeed like some ancient castle, perched on its craggy mountain top. As you see, the forester has to use a ladder to get to his castle. Many of the five hundred fire lookouts—"crows' nests," as they are called—that dot our national forests have situations as lonely and romantically beautiful as this.

Owing to fires, to bad cutting, or even to the seeding habits of some trees, there are many forest areas that must be planted all at once with trees of the same age. To keep up a supply of the seedling forest trees it needs, the government has established huge tree nurseries. You may look down the rows of such a nursery and see millions of seedlings of a single variety.

Seeds are gathered by the bushel, and where necessary they are "stratified." You can read all about that process in our story

about seeds. When the young seedlings are strong enough, they are planted in the nursery rows and grown there until they are ready to be put into their permanent forest homes.

Planting trees by the million is no easy job. It must be done by hand, as most of the trees have to go on mountain sides, where no machines can be used. To cover the greatest possible area in the shortest possible time, very young seedlings are used, scarcely more than two or three years old.

Of course there is no time to dig holes and to take all the pains that we should take with a pet tree in a garden. Gangs of men with crowbars make holes at the proper places, and smaller gangs follow them with the tree seedlings. These are dropped in the holes, and the "planting" is done with the feet. One or two good-sized, husky boots are pressed around the seedling, and the job is finished.

Foresters clear many lanes, or "fire lines," like the one below through our national forests to arrest the progress of any fire that may get started. If a fire does start, they seize the tools from such an emergency box as the one at the left, and clear more open space before the blaze.

Photos by U S Forest Service

If this sounds like pretty crude planting, the answer is that in the sort of places where it has to be done it is very successful. There are some failures, of course, as in all new planting, but the foresters go back in a year or two and replace the few trees that have died.

America's Future Supply of Timber

No one knows how many million trees are planted every year in just this way. From them and from the self-perpetuating forests already noted, America will get its future supply of timber. Private lumber companies still control vast areas of our forests, but most of the companies have been taught by the Forest Service that the old ways will not do. All the good companies are willing and eager to help along in this great work. And all must face and fight the greatest enemy of forests in the world. That is fire.

In dry seasons a forest of cone-bearing trees is almost as dangerous as a powder barrel. One smouldering cigarette end or a carelessly thrown match may set fire almost at once to the dry "duff" of the forest floor. If there is the least wind a terrific blaze will start and immediately leap up into the tops of the trees.

This makes a "crown fire," the most dangerous kind of forest fire known. For these evergreen trees are full of pitch and resin, and will burn like mad while they are still perfectly green. No deciduous tree will do this, so that all our most destructive forest fires have been in the regions of the evergreens. Seven times since 1825 there have been terrible fires of this type, each of them covering millions of acres. Not one living thing is left after such a crown fire, for besides the forest every village and many farm buildings in its path are swept away.

Even recently there have been disastrous forest fires. From 1916 to 1925 such fires destroyed twenty-one million dollars worth of timber, though that is not half of the total loss. Land that has been burned over in this way may not be ready for replanting for

many years, owing to the burning up of its humus soil. Reforestation of these "burns," as the foresters call them, is one of the toughest jobs of the Forest Service.

The service soon began a fire campaign that is one of the most efficient things conducted by the national government. To stop fires as they start is the best way to check them. But first you must find the fire. To do this the service established hundreds of steel "fire towers." These are scattered over the tops of mountains, and a forest ranger is constantly on guard in dangerous dry seasons. With his maps, binoculars, and compass he locates every suspicious puff of smoke. Maybe it is miles away, but that does not matter to him, for he has his maps all marked off in numbered squares.

How to Fight a Forest Fire

The moment he locates the fire on one of his squares he telephones to the nearest forest station for help. The official there has perhaps only a handful of men. But the government gives him authority to take all the men he needs, and he may even stop passing cars and commandeer the passengers for the job.

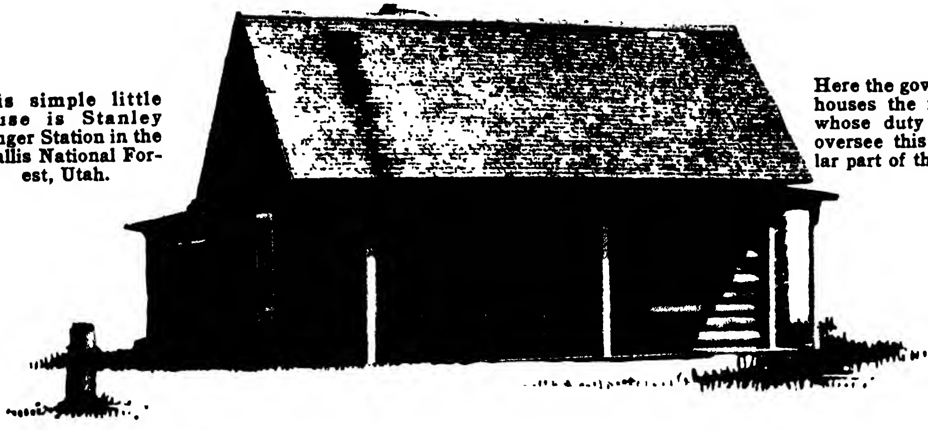
Fire-fighting tools have for years been scattered through the National Forests just for this emergency. Off the men rush, though not to put the fire out, for only rain can really stop a fierce forest fire. What the fire fighters do is to surround the fire with a ring of workers who will set limits to its spread. It will then be under control.

It is hot, dangerous, and terribly smoky work. It may go on for days and nights. Frantically the men work to clear an area so clean of trees that the fire cannot jump across it. This often means starting other fires which can be kept under control while they clear a given area. When the main fire reaches the area of the controlled fire, it will find nothing more to feed on, and will die out.

But in high winds the risk of the fire fighters' getting caught is very great, and a good many of them have been killed. In the effort to keep fires from spreading too fast, the Forest Service has cut "fire lanes" for hundreds of miles through the National Forests, and many private lumber companies have followed them in the practice. Fire lanes are strips cut through the forest; all the trees in a given strip are taken down. If possible the land is plowed like a field. Of course fire will sometimes jump these lanes, especially in high winds, but most forest fires are stopped by them.

Although the loss from fire is still very large, the work of the service is now so efficient that there probably will never be such fires again as came after the railroads first began to run in America, scattering sparks from the engines. Someone has estimated that more timber has been burned than has ever been cut out of American forests. That is a dreadful admission for us to make, for it will take years or possibly centuries to make up the loss.

This simple little house is Stanley Ranger Station in the Challis National Forest, Utah.



Here the government houses the foresters whose duty it is to oversee this particular part of the forest.

Reading Unit No. 41

GIANTS AND PIGMIES OF THE PLANT WORLD

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The size of the California big trees, 2–249
The "General Sherman" tree, 2-249
The smallest flowering plant, 2-249-50
A flower that is a yard across, 2-250
A fifty-pound fruit, 2-251
The largest leaf in the world, 2-252
The giant cactus, 2-252-53
Stems seven hundred feet long, 2-253

Things to Think About

What are the outstanding facts about the giant "General Sherman" tree?
What distinction has the duckweed plant?
How do elephants aid in distributing a plant parasite?
Why are dandelions widespread?
How large may some cacti grow?
How does the rattan grow?

Picture Hunt

Where does the century plant grow large? 2–249
A flower without leaves? 2-250
Which of our fruits is gigantic in size? 2-251
Have cacti any leaves? 2-252
Why do so many people want to see a sequoia? 2-253

Related Material

Why are some fruits feathery? 2-210-11
How do some fruits steal a ride? 2-211-12
How long do some trees live? 2-260

Leisure-time Activities

PROJECT NO. 1: Get a piece of redwood bark from a florist or tourist. Put it in a shallow dish of water and watch it sprout.
PROJECT NO. 2: Learn what are the largest and thickest trees near your home. Visit a museum of natural history, if you can, to see sections of giant trees.

Summary Statement

Some plants may be famous for their enormous trunks, fruits, flowers, or leaves. Others are famous for their extremely small size.

At home in Mexico our old friend the century plant grows to gigantic size, and towers well above the fence of candlestick cacti behind it. But in temperate zones it must be coaxed along indoors in a pot. Magueys (măg′wā) like this one give their fibers to be made into a variety of useful articles. And maguey juice, when fermented, is made into an intoxicating drink widely used in Mexico.

Photo by Andrew and Evalyn McNally Jr from their book, THIS IS MEXICO published by Dodd Mead & Company

GIANTS *and* PIGMIES *of the* PLANT WORLD

This Is a Story of the Freakish Sizes Seen in Some of the Green Things of the World

HUNDREDS of giant and pigmy plants are found in the world, some of them growing side by side, and others scattered far apart in remote regions. We will place some of these side by side, and see how they look together.

A million million is too great a number for us to be able to get any idea of what it really means. But it would take about a million million plants of duckweed to equal one of the big trees of California. Figure it for yourself if you like. There are about 5,000 plants of duckweed to an ounce, 80,000 to a pound, 160,000,000 to the ton, and the biggest and oldest sequoia tree has been estimated to weigh about 6,170 tons. If there were exactly 5,000 duckweed plants to an ounce this would make 988,160,000,000 in a ton. Often the plants are so small that it would take twice as many, or about 10,000 to weigh an ounce. We may add that duckweed is mostly water; so if we dried the plants it would take at least ten times as many again to make an ounce, or ten times a million million to equal the solid matter in a giant sequoia.

This giant sequoia of the forest is larger than its neighbors, but the groves of the big trees in California contain hundreds of specimens nearly as large. The sequoias (sē-kwoi′ȧ) were named for Sequoyah, a famous Cherokee Indian dear to the hearts of all Indian children. The great trees are evergreens with remarkably small cones and leaves, but they are the oldest and largest of all living things. There are several groves of them growing naturally in the high Sierras of central and southern California. Others have been planted in different parts of the world, where they are making good growth. The biggest of all is one that is named "General Sherman." This tree is between four and five thousand years old, 273 feet high, 102 feet around at the base, and at eight feet above ground it is over 27 feet in diameter. It is 18 feet thick at one hundred feet from the ground, and its largest branch, which is 130 feet from the ground, is over 7 feet thick. Its weight of about 6,176 tons is roughly a hundred times as much as a 600-ton locomotive.

Let us now see what the pigmy looks like.

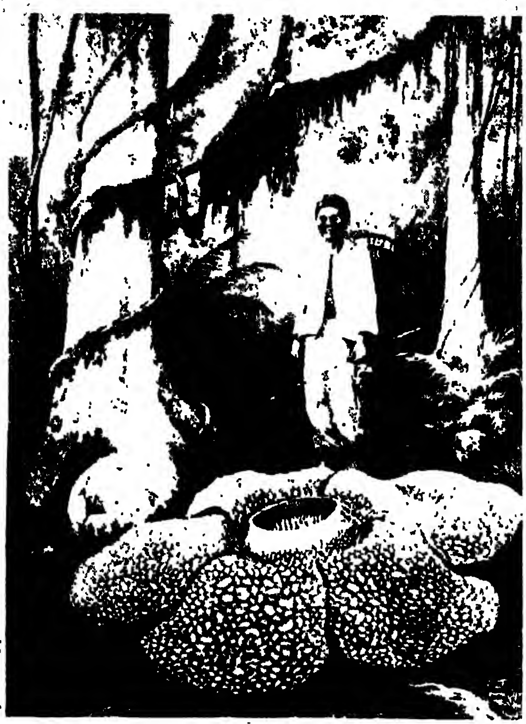
Floating on the surface of quiet ponds over much of the world you will find tiny flat green plants known as duckweed. Each plant usually has one to five leaflike structures, which lie flat upon the surface, and one or more hairlike roots, which go down about half an inch into the water. This duckweed, or "Lemna," is one of the smallest of flowering plants, the whole body of it being between an eighth and a quarter of an

inch across, and its total thickness scarcely a hundredth of an inch. It has no true stem, but from the margin of its floating leaflike organ there arise two or three flowers on very tiny stalks. The whole flower is smaller than a pinhead. There is another and even smaller flowering plant, Wolfia, which belongs to the same family as the duckweed and grows in similar places, but it is less common than the ordinary duckweed, or Lemna. This plant is only about one-fifth to one-tenth as large as Lemna. Duckweed and sequoias represent one of the smallest and one of the largest flowering plants in the world.

In many lawns and gardens you can find a low weed with small white flowers that bloom early in the spring. It is the common chickweed, and its tiny five-petaled flower is scarcely an eighth of an inch across. It weighs so little that it would take about a thousand of them to make a pound. It is not the smallest flower in the world, those of Lemna and Wolfia being much smaller; but it is one of the tiniest that you can easily see with the naked eye or are likely to tread under foot.

In Sumatra and India the elephants that go crashing through the forest occasionally kick loose a most curious flower, the largest known in the world. The plant that bears it has no common name, because it is very rare and only a few people have ever seen it. The first white man to find it was Sir Stanford Raffles, who discovered it in the dark rain forest of Sumatra in 1818. Since then a few more plants have been seen in India, but it is one of the rarest plants in the world, perhaps because its way of life is unique.

The plant was named "Rafflesia" (ră-flē'zhĭ-à), after its discoverer, and consists only of one gigantic flower about nine feet in circumference and a yard wide. There are no stems or leaves to the plant; the giant flower lies flat on the ground, and its only stalk draws nourishment from the roots of a vine to which it is firmly attached.



The strange, spotted, cushion-shaped structure in front of this East Indian boy is a flower of Rafflesia, the largest flower in the world. The plant lives as a parasite on a plant related to the grape, and has no stem or leaves of its own.

Even if it were not the biggest flower known, you would not want to use Rafflesia in a bouquet, for it is an extremely foul-smelling flower. After blooming it sets sticky seeds, and thereby hangs a tale of this extraordinary flower. Plant "parasites" (păr'à-sīt) must get themselves attached to the roots or stems of other plants in order to steal their food from those hosts. Rafflesia is said to get this accomplished by the feet of elephants. As the beasts go crashing through the forest some of the sticky seeds of Rafflesia cling to their feet. Later on, the elephant's foot may bruise the root of the vine upon which Rafflesia grows as a parasite. If one of the seeds sticks to the bruised roots, it will germinate and develop this largest of all known flowers. Such floral giants are nearly three hundred times as large as the pigmy chickweed, and no one knows how many times heavier.

Perhaps the largest and heaviest fruits

Photo by the Colorado Association

No one who enjoys the delicate pink flesh of the watermelon can fail to be grateful that the watermelon vine should produce so enormous a fruit. The fruits of the squashes, melons, and pumpkins are all large, and the watermelon is one of the largest. Compare it, for instance, with the tiny dandelion fruit.

are those that belong to the squash family, such as squashes, pumpkins, and watermelons. Under ideal conditions watermelons weighing up to 175 pounds have been grown, while fruits weighing about 100 pounds are not uncommon. Of fruits that grow on trees perhaps the largest is that of the jak tree, which grows only in tropical regions. One of the early writers said, "Its fruit is as big as a great lamb or a child of three years old." That was written in 1350, but modern measurements show that the fruit may weigh as much as 50 pounds, and it may grow to a length of about two and a half feet. It is oval or oblong, and averages about 30 pounds in weight.

The Curious Fruit of the Jak Tree

Apart from its size, the fruit is curious because it is borne only on the trunk of the tree. In the botanical garden of Rio de Janeiro there is an avenue of these trees, and the huge fruits, often six or eight on a tree, hanging by their stout stalks to the lower part of the trunk, make one of the strange sights in the plant world.

The outer rind is studded with huge warts, and the fruit can be opened only with the aid of some implement such as a hatchet. Inside there is a bananalike flesh and about five hundred seeds, somewhat like chestnuts. Very few white people like the flavor, but many of the poor natives use jak fruit as a food, and a single fruit will supply several meals for a fair-sized family.

A Fruit like a Double Coconut

Another large fruit is the double coconut of the Seychelles Islands. This is a palm, and its curious fruits, looking much like a double coconut, are smaller than the jak fruit; but because of their hardness, they are nearly as heavy.

The contrast between the giant watermelon or the jak fruit and the pigmy fruit of the dandelion is so great that you would hardly believe it if scales and rulers were not handy. While a strong man could scarcely stagger along with two jak fruits in his arms, a small child could carry a million of the light fruits of the dandelion.

When the dandelion finishes flowering it develops tiny achenes (ȧ-kēn′)—one-seeded fruits each with a small crown of fluffy down.

So light are these that a mere puff of air will set them flying, and it would be much harder to capture a million of them and put them in a bag than to carry the bag after you had done so, for a million of these fruits weigh only about two pounds. The fruits of the common yarrow, the fleabane, and the field daisy may be much smaller than those of the dandelion, which is five to ten times larger than they are. The fruits of the dandelion and some of its relatives are so constructed that they may be blown for long distances. Perhaps that is why dandelions with their flying pigmy fruit are found so widely spread, while the giant jak fruit, which drops with a great thud, has never spread far from its original home in India, except as a cultivated tree.

There are also great differences in the sizes of leaves. Some giant leaves are several thousand times as large as other pigmy leaves. The leaf of the heather in Scotland and Northern Europe is tiny, while the leaf of a palm which grows in the tropical forests of Northern Brazil is a giant among leaves. Let us look at the heather first.

It is a low evergreen shrub, with small cup-shaped flowers, and its branches are crowded with hundreds of tiny leaves. These are scarcely a fifth of an inch long, and have almost no blade; so the plant looks as if it were clothed with hundreds of fine, almost needlelike leaves, very short and green. Placed end to end it would take about sixty of them to make a foot and about 2,400 of them to reach the length of the Brazilian palm leaf. But even these figures give us no real idea of how much of a giant the palm really is, or of its great majesty.

The sahuaro, or giant cactus, such as these we see growing near Phoenix, Arizona, presents us with contrasts that are all its own. For it has such tiny leaves that you would scarcely suspect that it had any leaves at all; but the whole plant is more like a tall tree than an ordinary cactus, since it grows to a height of twenty feet or more.

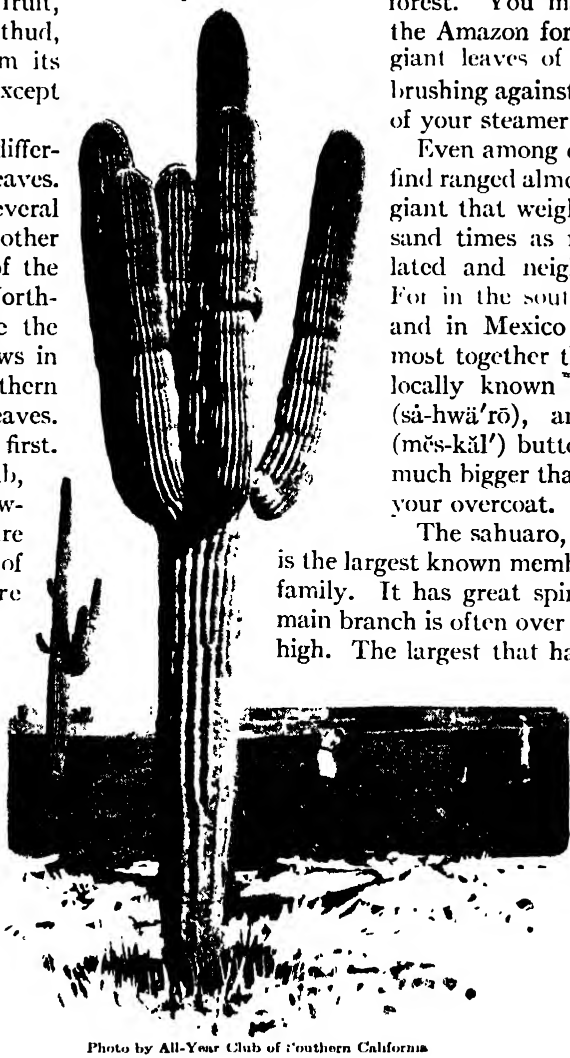


Photo by All-Year Club of Southern California

Growing in low unhealthful swamps, with their roots in black ooze, some of these giant palms of the Amazon Valley bear immense leaves indeed. In the banana we find a very large leaf—perhaps the largest simple leaf in the world. But these Brazilian palms have featherlike leaves that are highly compound. The whole leaf will be perhaps forty feet from tip to tip, but it has hundreds of slender leaflets, each of which may be eight or ten feet long. With a crown of such leaves at the summit, these palms are among the most graceful and majestic trees in the forest. You may travel along the Amazon for miles with the giant leaves of the great trees brushing against the upper deck of your steamer.

Even among desert plants we find ranged almost side by side a giant that weighs several thousand times as much as its related and neighboring pigmy. For in the southwestern states and in Mexico there grow almost together the giant cactus, locally known as the sahuaro (sȧ-hwä′rō), and the mescal (mĕs-kăl′) button, which is not much bigger than the button on your overcoat.

The sahuaro, or giant cactus, is the largest known member of the cactus family. It has great spiny ribs and the main branch is often over twenty-five feet high. The largest that has been found is thirty-six feet tall, and most full-grown ones are about as thick as a man's body. There is often, especially in young plants, only a single stem, looking a little like a swollen, very

long, and slightly-tapering green barrel. But older ones are much taller and have from eight to ten upward-curving branches, so that from a distance the plant looks like a great, swollen, branching candlestick. It has a few white flowers and red or purplish berries nestled among some white woolly hairs at the ends of the branches. These white blossoms are the state flower of Arizona, and the Indians use the fruits as food.

The huge body of the sahuaro, filled with a sweet watery juice, and the fantastic branching are in striking contrast to the pigmy mescal button. This is a tiny, warted, spineless cactus, about the size of a large overcoat button and three or four times as thick. It, too, has a watery but extremely dangerous juice, which was in use among the Indians before the days of Columbus. They make a drink of it more dangerous than opium. The government tries to prevent its manufacture, for it has a terrible effect on the Indians, and will even drive some of them insane.

Here again we find examples of curious and interesting giants and pigmies. The giant cactus, more than a thousand times as big as the mescal button, has a sweet, watery sap, while the pigmy contains a juice so terrible that men are ruined by it.

Photo by Yosemite Park & Curry Co

Through the base of the giant Wawona tunnel tree, one of the sequoias in the Mariposa Grove of Yosemite National Park, has been cut a tunnel large enough to allow the passage of an automobile. But the tunnel does not seem to have hurt the huge tree, which lives on and flourishes.

In the East Indies there is a group of palms known as rattans, perhaps best known to most of us because Malacca walking sticks are made from them. But did you also know that some of the stems of the rattan palm are the longest in the world—measuring as much as 700 feet, which is more than twice the length of the big trees of Califonria?

While rattans have extraordinarily long stems, they are almost ropelike in their growth and thickness. Their stems are so hard and tough that it takes a very sharp axe to cut through them. Rattan palms are very common in the forests of Ceylon, and everywhere they climb over trees. Usually they climb up to the canopy of the forest, and then run all through this airy perch. They make such a tangle that they often form a solid platform.

These huge seeds, some of them six inches across, are nothing but giant beans. The one in the center has had its cotyledons pried apart; between them lies the embryo, as in all seeds of the bean family.

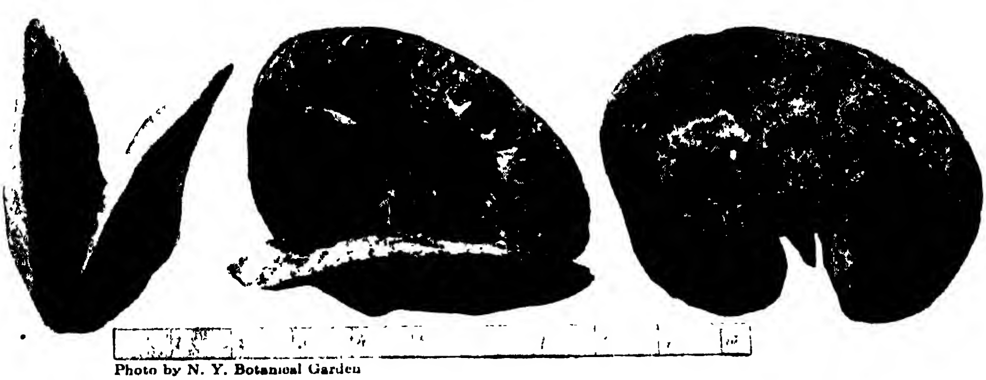


Photo by N. Y. Botanical Garden

BOTANY

Reading Unit
No. 42

GREAT NATURE'S QUESTION BOX

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For statistical and current facts, consult the Richards Year Book Index.

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Summary Statement

The world of plants has many fascinating marvels. Scientists study them and provide us with interesting explanations.

Photo by Nature Magazine

This is a question some man dropped into Nature's question box—why anyone should ever have tried to turn a juniper tree into a dog. It took a great deal of time and patience to produce this odd result, and oddities are always mildly interesting. But they are much more interesting when they happen naturally than when men manufacture them. After all, a tree should be a tree, and a dog should be a dog.

GREAT NATURE'S QUESTION BOX

Perhaps You Might Like to See How Many of These Questions You Can Answer

ALL Nature is one big question box. How? Why? When? What is it? What does it do? How does it do it? These and hundreds of other questions keep crowding up for answer. If you have read all we have told you about the plant world, you may feel that you can answer a good many of them. If you think so, see how many of those given below you can find the answer to —and after you have tried, read the explanation that we have given.

What Is Vegetable Ivory?

A certain number of billiard balls and many hard white buttons are made from vegetable ivory or Tagua. There is no plant with ivory tusks, like an elephant's, but there is one which gives us an extremely hard white substance which looks so much like ivory that it is sold in the trade as "vegetable ivory." All of it comes from South America, and most of it from Brazil, where the plant that yields it grows in the same forests with rubber trees and Brazil-nut trees. That means that vegetable ivory comes mostly from the Amazon Valley, although it is also found in Peru.

As elephants and walruses grow scarcer, vegetable ivory becomes more valuable. It grows on a smallish palm which develops so slowly that years are required before it flowers and sets fruit. Each of the six flowers produces one berry, but the six berries are joined together in one big fruit, which is inclosed in a hard, knobby, wooden shell. In the early stages the cells in each

berry are thin-walled and full of watery juice. As the fruit matures, the juice grows milky, then turns to a white paste, and finally becomes as hard and white as ivory, while the walls of the cells become thicker and thicker. While all this has been happening, the weight of the fruit has increased so greatly that when the ivory nut is harvested it may weigh over twenty pounds. The product is so valuable that the collecting of vegetable ivory has become a large business in South America.

When Is a Fruit a "Vegetable"?

Of course the word "vegetable" in this sense means a food that is eaten during the principal part of the meal—as potatoes and beans are—and not for dessert. In the more general sense, all fruits are "vegetables," since they all belong to the vegetable, or plant, world.

Now while it is true that most vegetables come from roots, like the beet, from bulbs, like the onion, or from leaves or stems, like spinach and asparagus, there are many other "vegetables" that are true fruits. They may not look much like a pear or an orange, but because they develop from an ovary and bear seeds inside them they are just as much fruits as a peach is. One such vegetable is the string bean, which we eat pod and all. Another is the cucumber, which is really a kind of berry. Still another is a true berry—the tomato.

Photo by Nature Magazine

Here is a prank that Nature herself has played. It is, you see, like a pair of Siamese twins among trees —and, to make it odder yet, the two elms are of different species. Something like this must have happened: Long ago the two trees, growing side by side, must both have been injured at the same time, so that their bark rubbed off down to the cambium layer. Each began to heal its wound at the same time, and the soft, growing tissues knitted together until the trunks were united as if they had been grafted.

Huge Members of the Melon Family

The largest fruit that is cooked as a vegetable is the pumpkin. It belongs to the same family as the cucumber, the squashes, and the watermelon. All of these plants bear immense berries which, because they have a hard rind, are called pepos (pē'pō)—from the Latin word for "melon." Another true berry used as a vegetable is the eggplant. And many other plants in the Tropics, where the eggplant first was found, bear fruits that are used only as vegetables. The best-known of these is the plantain, a kind of green banana. As a cooked vegetable the plantain is a staple article of food for millions of people.

Why Not Grow Oranges in Michigan?

Just to say that Michigan is too cold for oranges is not enough. The orange, the olive, and many other plants that grow naturally in warm regions can stand a good deal of cold—much more than true tropical crops like the banana and sugar cane. What oranges cannot stand is a growing season so short that there is not enough time for their fruit to mature; and of course they cannot bear fruit when the blossoms are killed by late spring frosts. Now it is true that the tree cannot stand the long bitter winters of Michigan, where temperatures often hover around zero; but it is also true that even such an extreme might be endured if Michigan were more like Florida in its general climate.

"Climate" is a good deal more than temperature. Many activities of plants, such as flowering and fruiting, depend for their success on various other conditions even more than they do upon temperature. One of the most important considerations for them is the length of the growing season. By that the fruit grower means the number

Photo by Cornell University

Lettuce is a plant that must have long days if it is to flower. This picture of six different lettuce plants will tell its own story. Each plant was raised under the length of day indicated on the pot.

of days when the conditions for growth are good. He counts the growing season as beginning when the spring days first climb to a temperature above forty degrees; it is over when the temperature falls below that point in the autumn.

Most plants seem to choose their climate with the length of the growing season in view. What the scientist calls "effective temperatures" are the ones that the fruit grower uses in reckoning the length of the growing season. Most of Michigan has a growing season of only 120 to 135 days. All orange-growing regions have a growing season of 230 days or more. That is the real reason why oranges do not grow in Michigan and in other northern states.

Photo by N. Y. Botanical Garden

The "wood" of a petrified tree looks like agate, and is smooth and heavy to the touch. It can be polished like any other ornamental stone. Yet it still keeps the markings and structure of wood, as you can see from the cross section of trunk in this picture.

Did you ever see a Mexican jumping bean? These strange "beans" are the fruits of a poisonous shrub (*Sebastiana pavoniana*) which grows on the uplands of Mexico. The plant is about five feet high and produces many fruits, which look enough like a bean seed to explain the name.

The fruits are about half an inch long, and have a curved outer side with a rounded keel, and two flat sides. If you put the fruit down on one of its flat sides, it will quickly jump up from the table high enough to turn over on the other flat side. If you put its curved side down it will take longer to jump, but will finally do so. From either flat side the beans will often jump as much as half an inch.

This is not caused by any miraculous power hidden in the bean. Inside the healthy fruit, which shows no opening of any kind, is the young grub of a Mexican butterfly. The egg from which it hatched was laid there before the ovary became a fruit at all. The full-grown grub spins a small web inside the fruit, and then, partly suspended by this web, it begins to eat—with the result that it is never perfectly still. Whenever the bean is put on a flat surface and the grub wriggles, the bean begins to "jump." Hence the Mexican jumping bean gets its name.

What Is a Monkey-Puzzle?

This is not a puzzle at all. It is a South American tree with branches so twisted and interlaced, and with leaves so prickly, that neither men nor monkeys can climb it—though both might like to, since it bears seeds that are good to eat. The tree is a native of Chile, and is often cultivated for its fantastic branching; it is perhaps the most interesting evergreen plant in our gardens. It is crowded with thousands of leaves about three inches long, all very stiff and tipped with prickles, so that it is impossible to get at the twigs. Then, too, the old leaves cling to the branchlets long after their green color is gone.

Photo by H. E. Zimmerman

This Hawaiian plant has chosen a most unexpected place to live—it grows only in or near volcano craters! That means, of course, that it thrives on conditions of temperature and soil that would kill most plants. Because its leaves are pointed and silver gray it is called the silver sword. As befits a plant so fond of volcanoes, it has flaming flower heads, yellow in the center with rose-purple rays.

What Is Carnauba?

When Edison was inventing the phonograph he found it very difficult to make the first records. These had to be coated with a substance into which the recording needle would trace its tiny grooves, and from which the record we buy could be made. The coating of the disk had to be soft enough for the needle to trace the groove, but stiff enough to preserve exactly every tiny scratch. The chemists worked with many kinds of fat, oil, wax, and various greases. None was really satisfactory.

When hope seemed about gone, a brand-new substance came to light and made the phonograph possible. This was carnauba (kär-nou′bȧ), a resinous wax found on the leaves of the carnauba palm, a tall fan palm which grows in the drier parts of Northeastern Brazil. Over ten million pounds of carnauba wax are scraped or shaken off these palm leaves each year, for besides going to the making of phonograph records, it is mixed with other substances to make varnish, insulators, and a wax for polishing floors and automobiles.

Why Is Vegetation So Luxuriant in the Tropics?

It is not always luxuriant there. More than half the tropical world is so dry and hot that nothing but desert cacti or stunted, spiny trees can grow. But in Northern Brazil, in parts of Africa and of India, and in most of the East Indies the vegetation is so dense that we may well wonder at it. In these areas are the great "rain forests." Many of them have already been disturbed by man's search for new timbers, drugs, fibers, and medicines, but in Brazil there still are large untouched areas of tropical jungle.

The reason for such forests is to be found in the favorable temperature and conditions of moisture. The trees of such

Photo by Norwegian State Rys

Did you ever see hay growing on the housetops? If not, look at this picture, which shows such an odd hayfield in Norway. The country people of many lands thatch their houses with sod bearing various plants native to the region. And if they get enough soil and moisture, the plants do not know the difference and go right on growing in their unaccustomed home. It is a strange sight to anyone not used to it.

regions have a long growing season, and a rainfall of from one hundred to five hundred inches a year! Under such favorable conditions plants cannot help growing; so such tropical jungles have the densest vegetation in the world

How Much Water Is in a Watermelon?

If we could find a watermelon that weighed exactly a hundred pounds, ninety-eight pounds of it would be water. Of course the "flesh" of a melon does not look like water; but in reality that pink substance consists of many thousands of tiny water-charged cells.

This seems an enormous percentage of water for a fruit to contain, but that is partly because one does not realize how much water is in many other foods. Here are some figures giving the water content of a few fruits and vegetables:

	Water
Watermelon	98%
Potato	75%
Cabbage	89%
Asparagus	90%
Apple	83%
Strawberry	90%
Carrot	85%
Parsnip	79%

Under natural conditions all living plant tissues have appreciable quantities of water. Active tissues, such as leaves, shoots, and roots, nearly always have more water than solid matter, and even ripe seeds that have dried in the air usually contain more than ten per cent of water. The water content of plant parts is not constant, but varies with the kind of part, its age, and the conditions under which it has been grown or kept. For this reason the figures in these tables are not to be considered as fixed. Figures giving the percentages of water and solid matter of mature leaves and seeds are given in the table below:

	Water
Tomato leaves	85 to 95%
Nasturtium leaves	80 ot 85%
Grape leaves	70 to 80%
Peach leaves	60 to 70%
Apple leaves	59 to 65%
Oak leaves	54 to 65%
Seeds of oats, wheat, corn, rice	10 to 18%

How Long Do Trees Live?

Among the oldest trees in the world are the giant sequoias, or "big trees," of California. Some of them are known to be about four thousand years old. Perhaps the next oldest are the dragon trees of the Canary

Islands, one of which is certainly at least three thousand years old.

Not quite so old as either of these is the ahuehuete, a giant cypress of the uplands of Mexico. When the Spaniards first arrived there it was hundreds of years old; its present age is probably about two thousand years.

But contrary to many fantastic tales most trees are not so old as these three famous ones. Few of the soft-wooded or coniferous (kō̆-nĭf'ēr-ŭs) trees live to any great age, and reliable records of hard-wood trees are hard to get. We should be able to count the annual rings and so to get an exact estimate if it were not that the rings get closer and closer together in extreme old age, and so are very difficult to count accurately.

From the best available records the extreme age of the following trees would seem to be well known. But we must remember that conditions must be perfect for them to reach these ages, and that conditions are so often imperfect that only exceptional trees grow to be so old.

Tree	*Extreme Age in Years*
Big tree of California	4,000
Dragon tree of the Canary Islands	3,000
Ahuehuete of Mexico	2,000
English yew	1,800
English oak	1,500
European lime tree	900
American white oak	800
Sycamore maple	600
American black walnut	500
Douglas fir	500
Olive tree	400
American white pine	200

This odd plant, with its enormous latticework leaves, is named Monstera. The surprising holes in the leaves are formed by the death of cells at those points. The flower, as you see, has a spike surrounded by a spathe. It looks a bit like our jack-in-the-pulpit, and is indeed one of jack's near relatives. The holes in the leaves allow the light to reach the lower parts of the plant.

Most of these are timber trees; the ordinary ornamental trees are much shorter lived. Nearly all fruit trees live less than one hundred years, and some, like the peach, hardly exceed thirty years.

What Makes the "Eyes" in Bird's-eye Maple?

No lumberman can tell whether a maple will have bird's-eye wood or not until he cuts the tree down. The peculiar and beautiful markings, shaped like a bird's eye or a narrow lens, are quite accidental. They occur, in fact, in other trees besides the maple.

The tree that yields bird's-eye maple lumber is the same species that gives us maple sugar, and is usually called the rock, or hard, maple, by the lumbermen. It has a close-grained, compact, rather hard wood, and for some unknown reason some of the individuals give us the beautiful bird's-eye effects. All we know is that the markings are usually caused by the presence of dormant buds. These buds maintain their position in the bark, slowly growing as the tree grows in diameter, and leaving irregularities in the wood much like those where a

Photo by British Museum

Looked at closely, as you see it above, this queer New Zealand plant looks more like a soiled snowball than a sheep. But it came honestly by its common name of "vegetable sheep." For a group of these plants growing together does look from a distance like a flock of sheep—as many a tired shepherd has found to his cost, when he toiled up some steep hill to it, supposing it to be one of his flock. The woolly effect, which comes when the plant is young, is due to its odd habit of growth. The leaves are very tiny, the branches short and densely crowded together. It is a thrifty arrangement, and very valuable to the plant, for it cuts down loss of water, and our "sheep" inhabits rather dry regions.

branch develops but very much smaller. But why the tree should behave in this way is still a mystery. The condition does not strengthen the wood, but it makes an irregular grain, for the eyes are really small knots. It is just one of the many haphazard variations that occur. This variation happens to be of no great significance in the life of the tree, but the wood is greatly prized by furniture makers.

Does the Rain Tree Cause Rain?

Several tropical trees are supposed to cause rain. One of them (*Pithecolobium samman*), a tree with gorgeous scarlet flowers, is famous the world over. Even under a perfectly clear sky there are always a few drops of moisture falling from its leaves. But it never yet caused a real rain. What happens is very much simpler.

The leaves of the rain trees are much loved by cicadas, which are relatives of our common seventeen-year locusts. These insects visit the trees regularly and in considerable numbers, and they steadily suck the juice from the leaves, for it is their chief food. Indeed, they are so greedy that they always suck too much—so much, in fact, that they are constantly ejecting the surplus as "rain."

Several other trees that have no cicada visitors are known as "rain trees," and ignorant natives think they do indeed cause rain. Of course that is nonsense. What many tropical trees often do is to respond to the approach of rain by moving their leaflets, closing their flowers, or opening their seed pods. All such movements are caused by changes in the amount of moisture in the air, but are never the cause of it. These rain trees merely warn of approaching rain.

Does the Century Plant Bloom Once a Century?

Century plants bloom only once, and then they die. For a long time they go on adding to the rosette of basal leaves, and some few even produce a short trunk. But in this stage they never flower. After many years, in no case so many as a hundred, the plants send up a tall flowering stalk from the very center of the rosette of leaves. It is formed by the terminal bud of the plant, which means that no more leaves can be produced. This flower stalk may be several months, or even a year or two, in reaching its full height—sometimes it will be twenty or thirty feet tall; at its top there will be a candelabra-shaped cluster of flowers, followed in a few months by the fruits. Then the plant dies. Most century plants live less than fifty years; often, as in the case of the sisal hemp plant, they live only about twenty.

Photo by H E Zimmerman

Look closely at this plant, for it is most surprising. It has tomatoes above ground and potatoes below! Of course that means that it is not really a single plant at all, but parts of two plants that have been grafted together. This was done, one might say, "just for fun"—to show that such a graft is possible. The reason that it was possible, and easily possible, is that the tomato and potato are closely related.

What Is Polished Rice?

It is the ordinary white or pearly-colored rice one buys at the grocer's—and at one time it was a frequent cause of the dreadful disease known as beriberi (bĕr′ĭ-bĕr′ĭ).

The Little Brown Coat on Rice

Rice, as it is harvested, is brownish in color, for around every seed is a little brown coat. Millions of people, like the Chinese and the natives of India and the Pacific islands, use rice as commonly as we do wheat. Now some of them, many years ago, decided that boiled rice with its brownish coat looked dirty, so they invented various ways of brushing the coat off. It is known as "rice polishing," and to-day there are many machines for the purpose.

But it was soon found that in brushing off the brown coat one of the most valuable parts of the rice was being eliminated. The lack of it, in the countries where a great deal of rice was eaten, caused thousands of deaths, many more thousands of cases of disease, and a partial anemia from which whole populations suffered. This was the dreaded beriberi.

There is little beriberi to-day, because people who use rice as their chief food commonly use the untreated kernel or supplement the rice with other foods. We in the West have such a varied diet and use so little rice that no one suffers from eating it polished.

What Are the Everglades?

Nearly all southern Florida is a sandy waste of pine trees, with grasslands and wild flowers scattered pretty freely through the groves of evergreens. It is very hot and dry, in some places much like a desert, and it supports several species of cactus.

But in the region west of Palm Beach and stretching for many miles toward the south, there is a very different sort of landscape and vegetation. Covering thousands of acres in this part of the state there is a great shallow swamp known as the Everglades. The water there is not deep, and for miles the region is covered with a dense vegetation of saw grass, among which grow some of the largest cypress trees in Florida. Many other trees and shrubs, and even some palms, are

scattered through the area, which looks much more like a tropical jungle than like a part of the United States.

Recently the national government and the state of Florida have drained parts of the Everglades, and the raising of subtropical fruits has already been begun there.

Why Do Aspen Leaves Tremble?

Most leaves have a leafstalk that is round in cross section and stout enough to hold leaves steadily in their usual position. But the leafstalk of aspens is flattened in a plane perpendicular to the leaf blade. This flattened petiole is very pliable and bends easily in gentle winds, much as a flat strip of metal or wood will bend more easily than a cylindrical one. This accounts for the fact that aspen leaves are constantly trembling as long as there is a slight movement of air. So, the tree seems to be always shivering.

Photo by Australian Govt

This tree *does* look like a bottle, does it not?—a giant bottle holding a bouquet of green boughs. That is why it is commonly called the bottle tree. It grows in Australia, and is among the largest trees in the world. The cacao tree is related to it; its nearest connection among our own trees is the linden.

What Is a Liana?

A liana (lē-ä′nȧ) is a woody vine that usually grows long enough to climb up to the canopy of the forest. Often, especially in the Tropics, lianas will not only reach the canopy, but will travel a long way through it, making a terrible tangle.

Some lianas climb by means of great hooked prickles, which catch hold of any handy anchorage for support. Many of them, especially in tropical rain forests, where they are very common, have stems as thick as a man's body. But even if they are treelike in girth, lianas always need some support, just as any other vine does.

Some of these vines, such as the wild grape, grow in the temperate part of the United States. The grape may have a stem one hundred feet long; but certain tropical lianas grow to over four times that length and usually show a peculiar stem structure.

What Is the Double Coconut?

When Dutch and Portuguese navigators sailed to the East Indies in the sixteenth century, they often found floating in the Indian Ocean a very curious fruit. For many years they brought home samples of it, some of which weighed as much as sixty pounds. No one knew whence it came.

Years later it was discovered that this gigantic seed was borne by a palm, the "coco de mer" (dē mĕr′), or "coconut of the sea," which grows only in the Seychelles (sĕ′shĕl′) Islands. These are small mountainous islands just south of the Equator and about one thousand miles east of Africa. The palm came to be called the double coconut because the seed looks a little like two huge coconuts merged into one great fruit. But it is a very different palm from the true coconut palm, for it has fanlike

leaves and bears male and female flowers on different trees. Ten years are needed to ripen these strange double coconuts, which are nearly the largest and hardest fruits known.

What Is Tannin?

It is the strongly astringent juice extraced from many plants, and from many different parts of them. From the time of Moses people have valued tannin because without it the tanning of leather is almost impossible. The extract of the plant is rubbed on the skin or soaked into it, and turns the hide into leather.

Tannin is really the name given to a group of compounds which are produced by plants and which have certain peculiar properties. These substances are found in the pods of some acacias, in the hulls of walnuts, in many trees yielding a substance called "kino," in some tropical mangroves, and in many other trees. The astringent (ăs-trĭn'jĕnt), or puckering, effect of unripe bananas or persimmons is due to tannin. In the United States and Europe the chief source of it is oak or hemlock bark. It is from used, or "spent,' bark that "tanbark" comes. You may have seen this used to deaden the noise in a circus ring. But its first and great use has always been to give its tannin to make leather.

Unlikely as it may seem, this pretty potted plant is a two-year-old apple tree. The variety is known as the Reverend Wilkes, and is 18 inches high. It proudly bears four apples, the largest of which is 5½ inches in diameter. All four apples together weigh 6 pounds, 5½ ounces, and make quite a burden for the little plant!

What Is a Floating Island?

It is something a good deal more interesting than the pleasant dessert we all know. If you took a journey up the Nile or the Amazon you would find patches of vegetation floating in the water. They might be only a few feet square, or they might measure nearly half an acre. They are carried along like a raft, and on the largest of them are living bushes, or even trees.

Such floating islands of vegetation have an interesting history. In rivers like the Nile or Amazon there is a tremendous difference between high and low water. More than a thousand miles up the Amazon the high-water mark at the end of the rainy season will be sixty feet above water level at the end of the dry season. This means that thousands of square miles of flat country are covered once a year by floods.

Now in these enormous shallow lagoons all sorts of vegetation gets started during the rainless months. The plants would be covered during floods if it were not that they are shallow-rooted and float on a mass of dead vegetation on which they grow. The vegetation gradually accumulates, forming a compact raft, with no roots to anchor it to the earth. When an especially wet season, with high water, comes along, this mass escapes from its quiet lagoon, and drifts out into the main channel of the river.

In the White Nile these floating islands are so numerous that they sometimes make the river impassable for steamers. The natives call them "sudd," because they are often bound together by sudd grass, a half-creeping wiry grass that binds the mass as securely as a rope would.

Reading Unit No. 43

HOW TO KNOW THE TREES

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Trees to be Studied

Cone-bearing trees, 2–266-69
The walnut, birch, beech, and oak, 2–270-71
The elm, osage orange, magnolia, and tulip tree, 2–272-73
The sweet gum, sycamore, locust, and sugar maple, 2–275
The flowering dogwood and white ash, 2–276

Picture Hunt

Which pine has five needles? 2–266
Which evergreen has short, four-sided needles? 2–267
Which evergreen has tiny, stalked, flat needles? 2–268
How large are the cones of the Douglas fir? 2–269
Which trees have compound leaves? 2–270, 275-76
How can you distinguish between a beech and a birch? 2–270-71
Which trees bear acorns? 2–271
Which tree has branches like the ribs of an umbrella? 2–272
How did the tulip tree get its name? 2–273
Which tree has star-shaped leaves? 2–274
Which tree has brown and white patches on its trunk? 2–274
How many leaflets has a locust leaf? 2–275
Which tree has opposite, palm-shaped leaves? 2–275
Which tree has leaves with parallel ribs? 2–276
How many leaflets has a white ash leaf? 2–276

Leisure-time Activities

PROJECT NO. 1: In the spring visit a tree daily and make a collection of leaves showing daily growth. Start with a very tiny one and continue until you get a full-sized one.

PROJECT NO. 2: Make a collection of pressed leaves from all the different kinds of trees in your neighborhood and in the parks. Label each sheet on which you paste the leaf.

PROJECT NO. 3: Make a large map of ten square blocks in your city, representing each tree with a disk of colored paper. In the key, show the kind of tree each disk represents.

Summary Statement

You can learn to recognize any tree by its bark, leaf, twig, bud, flower, or fruit if you make a serious attempt to study these interesting friends of man.

Pines are the most familiar of the cone-bearing trees. Their leaves are more like needles than those of any other evergreen. The white pine, above, bears its needlelike leaves in clusters of five. Its seed cone is five or six inches long. The tree grows as high as 150 feet and is straight and graceful.

Photos by Davey Tree Expert Co

The yellow pine has smaller cones and bears its needles in groups of two or three. Here, as in the pictures of the white pine, details of bark, cones, and leaf clusters are shown at the right.

The American larch, or tamarack, is a very graceful cone-bearing tree. It looks like an evergreen, but its leaves fall every year. The leaves are needlelike, but are smaller than those of the pine and are not borne in bundles; the cones are about half an inch long. This tree grows 50 to 100 feet high.

Photos by Davey Tree Expert Co.

The red spruce sometimes grows 70 to 80 feet high; its cones are under 2 inches long, its bark scaly but not ridged. Like all spruces, it has short, four-sided needles which point in all directions.

The Canadian hemlock is a cone-bearing evergreen which may reach a height of over 100 feet. The hemlocks have short, flat leaves, usually called needles.

These leaves have petioles and grow in two ranks, or tiers. The cones are about the same length as the leaves. The bark has flaky scales.

'hotos by Davey Tree Expert Co.

The bald cypress has round cones, short, flat leaves, and flaky bark. Unlike most conifers, it is deciduous.

It has queer, cone-shaped "knees" growing up from the roots, and is found in damp places.

HOW TO KNOW THE TREES

Photos by Davey Tree E   Co., and U S Forest Service

The coast redwood, above, grows 200 to 300 feet high, but never so high as the giant sequoia, its near relative. Its flat needles are longer and darker in color than those of the sequoia.

Photos by Davey Tree Expert Co.

The, Douglas fir is another proud tree which may reach a height of 250 feet. Its leaves are flat, and its cones, like those of the redwood, very small for so big a tree. It grows in the Northwest.

HOW TO KNOW THE TREES

Now we come to the deciduous trees—those which lose their leaves every winter instead of remaining always green, as do the evergreens. These trees have flowers, not cones, to form the seeds. We may begin with the black walnut, above. It grows 50 to 100 feet tall. It has a long, compound leaf, and a fragrant bark that becomes rough and ridged as it ages. It bears its pistils and stamens in separate flowers; the flower with stamens is called a catkin. The fruit is a rough-coated nut which ripens in October.

Photos by Davey Tree Expert Co.

The paper birch is known at once by the chalky white bark that splits off so readily. It has two kinds of flowers, both in catkins. Its fruit is a samara, a single-seeded fruit with a coat lengthened into a long, light wing which floats it through the air. The tree rarely grows over 75 feet high. Its leaves are simple and toothed. In all these cuts, squares in the background represent square inches.

HOW TO KNOW THE TREES

The American beech, above, sometimes grows to a height of 100 feet. The pictures at the right show clearly its smooth, grayish-white bark, its deeply-veined leaves, and the little nut with the spiny coat which is its fruit. It has two kinds of flowers, one bearing pistils, the other stamens; the flowers with stamens are catkins. In this last trait the beech is like the oak, its near relative.

Photos by Davey Tree Expert Co.

The American white oak is one of our most valuable trees because of its fine wood. Its height is not over 80 feet, but its girth is considerable—it may be as much as 6 feet in diameter. The branches spread wide from the tree. The bark is gray. As for the fruit, who does not know the acorn with its wrinkled cap? The leaves of the oak are deep-lobed, and so thick and strong that long after all the other deciduous trees are bare, the leaves of the white oak still hang, brown and dry, on the stems.

HOW TO KNOW THE TREES

Though you will probably be much surprised to hear it, the stately elm, above, is a relative of the nettles. It is one of our most beautiful trees, tall and graceful, spreading its crown of leafy branches far over our heads like an enormous umbrella. If you want to see it in its greatest glory, walk down the elm-shaded streets of some old New England town, where the magnificent trees make the whole highway a chasm of green shade. Elm leaves are harsh to the touch and have toothed margins. The bark is rough, with deep ridges. The flowers are not showy, but they are "perfect"—that is, all the parts are borne in the same flower. They open before the leaves appear. The fruit is a round samara (săm'ȧ-rȧ); that is, the seed is inclosed in a papery coat extended outward into a thin scale all around it. With this sail it floats on the wind.

Photos by Davey Tree Expert Co

The osage orange is another unexpected relative of the nettles, just as is the elm. In spite of its name, the osage orange is not an orange at all. Its name comes from the round, hard, yellowish fruit, which—as you can see in the picture—looks somewhat like an orange. It would not taste like an orange, however. This tree grows naturally in the south-central part of the United States, and is often cultivated, not only alone, as in our picture, but also to form hedges. It grows from 20 to 50 feet high. It has a milky sap, and thick leaves with smooth margins and a sharp spine generally growing beside the petiole. It does not have perfect flowers, as the elm has, but bears its pistils and its stamens in separate flowers. Both the seed-bearing and the pollen-bearing flowers are small and rather inconspicuous.

Most tall trees have flowers so inconspicuous that we scarcely notice them, but the magnolia is an exception. It grows to a height of from 50 to 90 feet, and yet it bears large and beautiful blossoms, sometimes three inches across. These flowers are white or pinkish in color, and pleasantly fragrant. The leaves are ovate in shape, pointed at the tip, with smooth margin The magnolia is also called the cucumber tree.

Photos by Davey Tree Expert Co.

The tulip tree is one of the most beautiful of all native American trees. It is also called white wood, or yellow poplar—though, like the magnolia, it is allied to the buttercups and not the poplars. It may reach a height of 150 feet, with stem straight and proud. The bark is of fine texture. The leaves are three-lobed—the end lobe blunted in so odd a way that you cannot fail to recognize it. The greenish-yellow flowers suggest a tulip—hence the common name of the tree. These flowers are slightly fragrant.

The sweet-gum tree has a resinous sap which is gummy when it oozes out and so gives the tree its common name. The leaves are palmately lobed and so regularly formed as to appear almost star-shaped. At first glance they look like maple leaves, but are firmer and have a more finely toothed margin. There are two kinds of flowers, both inconspicuous. The dry, round fruit may hang on the tree all winter. On the younger twigs are irregular cork ridges or wings by which you can easily identify this beautiful tree.

Photos by Davey Tree Expert Co.

The American sycamore is also called buttonball, or sometimes plane tree. It has large, downy, palmately lobed leaves and inconspicuous flowers of the two kinds. There is a dry, ball-shaped fruit that hangs on the tree all winter. The bark is smooth and scales off in very large plates, leaving the trunk bald and white as shown by the white patches in the picture. In time the bald spots darken.

HOW TO KNOW THE TREES

The locust is a member of the pea and bean family, as you will quickly guess when you examine its flowers. They are borne in long clusters and are white and fragrant. The leaves are delicate-looking, like the flowers; they are compound, with many leaflets. But the bark of an old locust is rough and furrowed, and the wood is very durable. The tree may grow to be 80 feet high, but always remains graceful

Photos by Davey Tree Expert Co

The sugar maple is the tree whose sweet sap is collected in early spring and made into maple syrup or maple sugar. It is a large, handsome, very symmetrical tree. The young twigs are whitish-brown, the older bark dark and rough. The leaves are simple but deeply lobed, with from 3 to 7 lobes. No leaves take more gorgeous coloring when the first frosts come. The flowers are small and arranged in groups—a dainty sight in spring. The fruit is sometimes called the maple key; it consists of winged seeds in pairs.

Photos by Davey Tree Expert Co.

The flowering dogwood brightens many a country road in spring with its beautiful, showy flower clusters of pink or white. The flowers themselves, to tell the truth, are small; what we usually think of as "petals" are really four large white bracts, or specially modified leaves. The ordinary leaves have curved parallel ribs.

Photos by U. S. Forest Service

The white ash, which reaches a height of 80 feet, has gray, furrowed bark and tough wood. The small flowers, which appear before the leaves, are of two kinds, and only one kind—either with pistils or with stamens—grows on any one tree. Of course only the trees bearing flowers with pistils have fruit. This fruit is a samara with a single long wing. The leaves are compound, commonly with 7 leaflets.

Reading Unit No. 1

A MARVELOUS LIVING SUBSTANCE

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How flies taught Redi, 2 278

What Leeuwenhoek's microscopes taught the world, 2 278-79

Schleiden and Schwann find out something of how living things are built, 2 279-80

What protoplasm does for us, 2-279

What the cell theory means, 2-280

The remarkable human machine, 2 280

How do we know that protoplasm is alive? 2-280

Things to Think About

Why did people once think that frogs were formed out of mud?

How was it discovered that veins and arteries are joined?

How are all living things constructed?

What substance is present in all living things?

What does the cell theory teach us?

How do living things get bigger?

Picture Hunt

What keeps boys alive and active? 2-278

What part of a cell divides before two cells are formed? 2-279

How does one cell become two? 2-279

What are the two main parts of a cell? 2-279

Related Material

Redi's experiments with flies, 13-371

How did Leeuwenhoek make his microscopes? 13-362-63

How do plant cells divide to make more cells? 2-9-10

Summary Statement

Living things are made up of chemical elements, just as are earth, air, water, rocks, etc. But in living things these elements have combined to form a remarkable substance called protoplasm. This substance turns food into more protoplasm, throws off wastes, burns food for energy, and grows by dividing. Protoplasm is the living part of cells. When these cells are doing their work and dividing, we grow.

These young people are extremely glad to be alive. But probably they know a great deal more about what makes an automobile go than they know about what makes their own bodies "go," or how it is that those amazing machines can move and think and talk and see and hear and feel!

Photo by H Armstrong Robe

A MARVELOUS LIVING SUBSTANCE

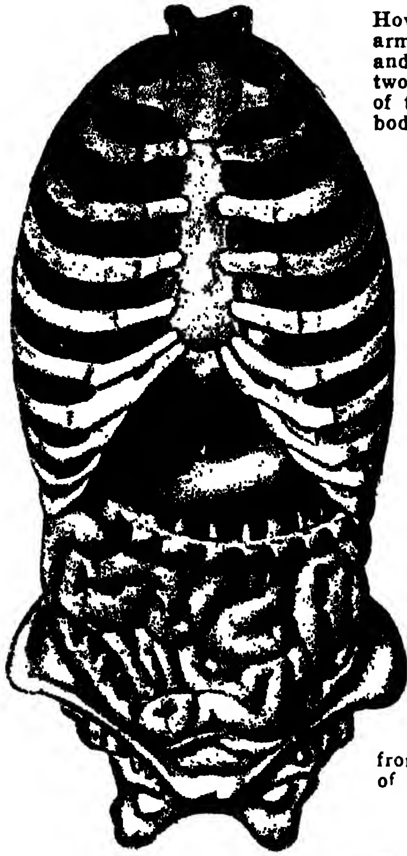
Far More Clever and Complex than Any Machinery We Have Ever Invented, the Human Body Is a Busy Machine That Lives and Obeys Our Commands

EITHER things are alive or they are not. Plants and animals are alive. Rocks, earth, water, air are not. Yet all these things, the living or "animate" (ăn'ĭ-māt), and the others, the "inanimate" (ĭn-ăn'ĭ-māt), are made of exactly the same things—the same chemical elements. Then what is the difference between them?

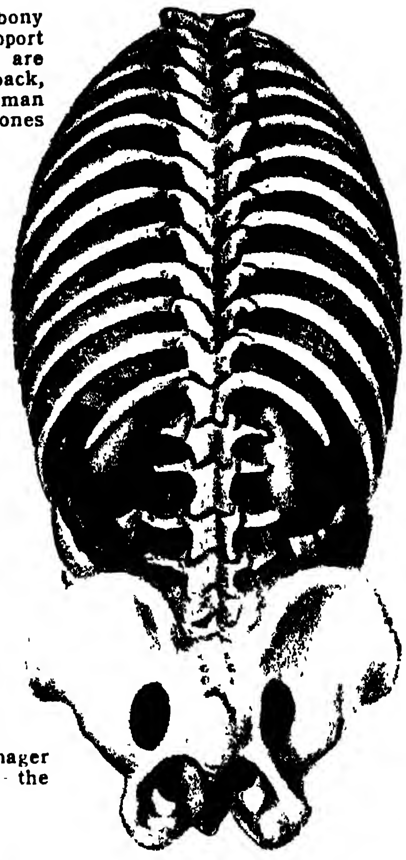
It took man a long time to find out what it is that makes some things live. At first, just as people thought the earth was flat, they believed that rocks and stones could turn into living things. They thought that frogs simply grew out of mud, and flies' grubs out of spoiled meat! Then in 1668 an Italian doctor named Redi (rā'dē) discovered that flies lay eggs. He grew very much excited, and cried, "No, living things do not spring up by themselves! All living things have parents. All life comes from life." And he began telling this to all the other scientists. But the scientists of the time would not believe him even when he showed how grubs come from flies' eggs, and flies grow out of grubs. They even grew very angry. "Some living things spring up by themselves," they kept arguing. But Redi knew better, and a terrible fight began that lasted a very long time. When it was over, everybody knew that Redi was right—that every plant comes from another plant, and every animal from another animal; and that there is no other way for any living thing to get into the world.

"But what is it that makes us alive?" other men wanted to know. And though they were trying hard to learn, they could not get very far. To see why they could not, let us pretend that you are an eager scientist living at that time. You work away in your laboratory, testing Redi's experiment with the flies' eggs. But you cannot go much further because you have so few tools to work with—only a little hand lens or magnifying glass that makes things slightly larger. So you spend your time cutting up animals like frogs and cats and rabbits, to see what they look like inside.

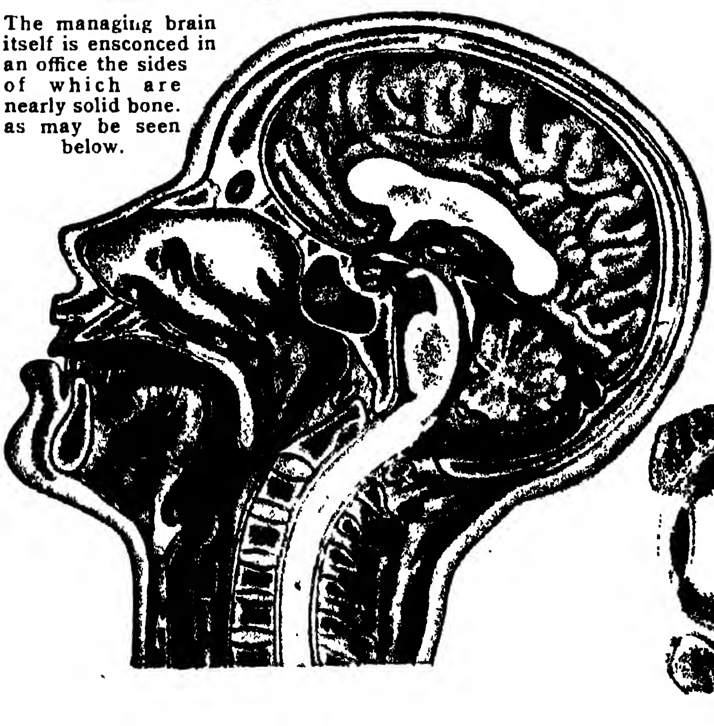
Then, in 1675, you hear that at Delft, in Holland, there is a man called Leeuwenhoek (lā'vĕn-hōōk), a lens polisher turned scientist,



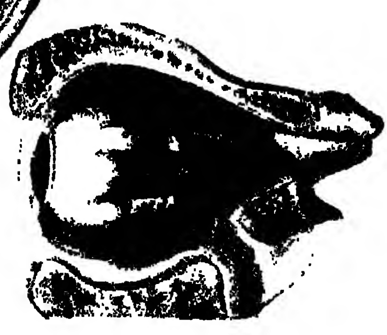
How cunningly is our bony armor contrived to support and protect us! Here are two views, front and back, of the trunk of the human body, showing only bones and the vital organs they protect. Note how snugly and firmly the whole column fits into the hollow of the pelvic bones, and how the ribs stretch around the delicate lungs and heart like enfolding arms. The heart is best protected of all under the flat, stout breastbone which almost covers it. The spinal column, running all up and down the back, not only supports the whole but makes a long, supple tube like a secret tunnel, through which may be relayed all manner of messages to and from the general manager of the whole system - the brain.

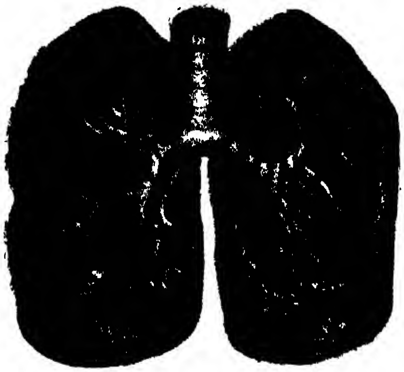


The managing brain itself is ensconced in an office the sides of which are nearly solid bone. as may be seen below.

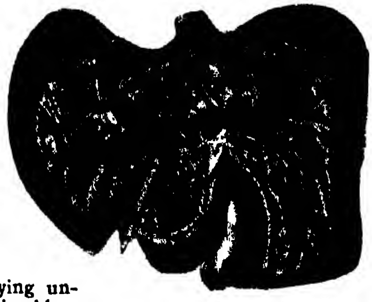


As this cross section of head and neck will show, our heads are largely incased in bone. There are the closely knit skull bones over the brain, the branched cavity. of the nose, with its bony sides, the strong, bony jaw, and the teeth, which are rather like a specialized kind of bone. And the delicate and precious eye, as shown below, is sunk deep into a socket of bone which is like a cave with an overhanging roof.

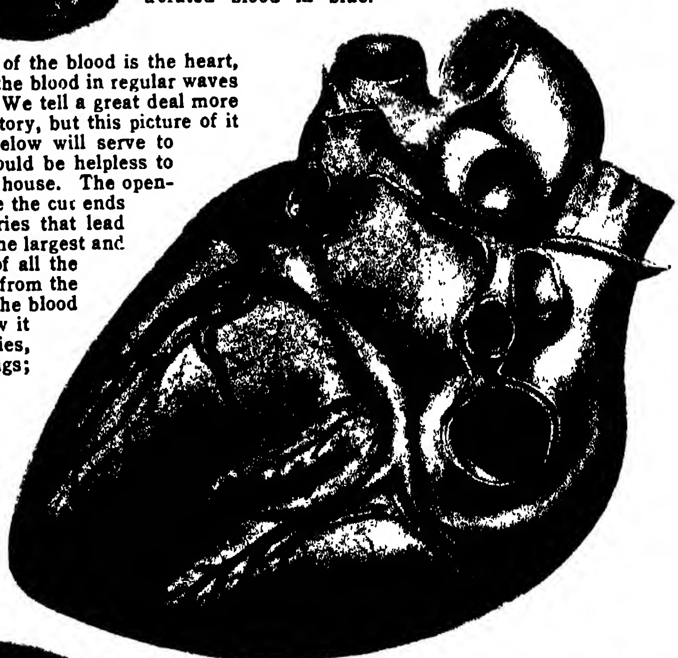


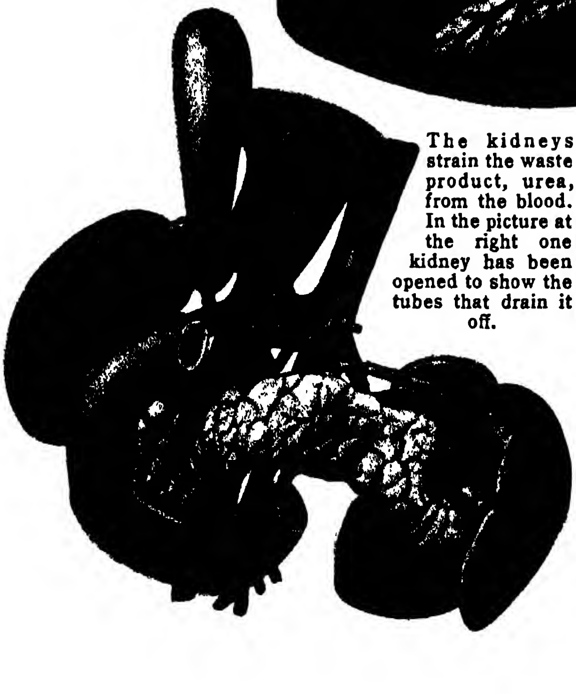


In the lungs the blood is "aërated," or aired; there it discharges its carbon dioxide and takes on oxygen. At right and left are sections of lungs, with the vessels carrying aërated blood in red, those carrying unaërated blood in blue.



The central pumping station of the blood is the heart, whose steady beating sends the blood in regular waves or pulses all over the body. We tell a great deal more about the heart in another story, but this picture of it as seen from behind and below will serve to remind us that the blood would be helpless to nourish us without its pump house. The openings shown in the picture are the cut ends of the great veins and arteries that lead into and out of the heart. The largest and topmost is the aorta, chief of all the arteries, which arches down from the top of the heart and carries the blood to the abdomen. Just below it are the two pulmonary arteries, which take blood to the lungs; the four smaller blue openings below them are pulmonary veins, which bring it back. The other blue openings, one turned upward, the other toward us, are the great venae cavae, or chief veins.

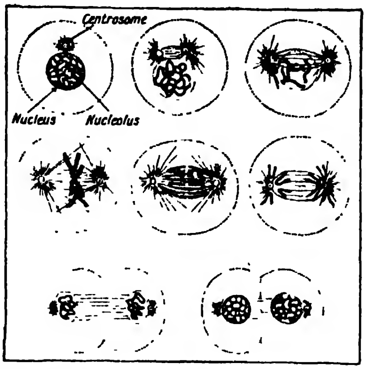




The kidneys strain the waste product, urea, from the blood. In the picture at the right one kidney has been opened to show the tubes that drain it off.

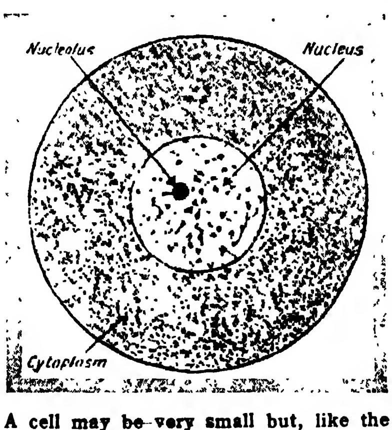
At the left you can see the kidneys—easily picked out by their shape—with the organs near them: the spleen at the extreme right, the pancreas in the middle, and the gall bladder sticking straight up like a handle, with a piece of the liver beside it. The great stem and some of the branches of the aorta, in red, and the lower vena cava, in blue, can be seen in both pictures.

who has perfected an instrument through which he can see very tiny things. This instrument, called a microscope, is made of a number of lenses working together. The microscope has opened up a new world in which there live tiny animals without heads or tails or legs. They are just little blobs that wriggle about in anything wet. You, far away in Italy, get very much excited. You had never thought that there were such small animals. You also learn that through the use of his miscroscope Leeuwenhoek has discovered that the arteries, the blood vessels that take the blood from the heart, and the veins, which bring it back again, are joined by tiny tubes, the capillaries. "So now," you say, "we are sure just how the blood flows in a complete circle through the body." You would like to get yourself a microscope, but that is rather expensive. So you just keep plodding away, cutting up animals and writing about what you find for the medical books. After years spent in study, you die. And you have not found out what it is that makes us live.



Above are the stages in mitotic (mī-tŏt'ĭk) cell division. They commonly take place when one cell becomes two cells. The nucleus divides first. Those coiled threads in it—see top middle cell—are the chromosomes (krō'mō-sōm). They are paired before they separate, and carry the genes (jēnz), which control an individual's hereditary traits.

But other young and eager scientists go on with the work. They make better microscropes which enlarge things a thousand times, instead of just two hundred, as Leeuwenhoek's did. Under these high-powered microscopes they study still tinier creatures, some of which turn out to be disease germs. They study the structure of plants and animals. They discover many things.



A cell may be very small but, like the atom, it is made up of various parts. A living cell consists of cytoplasm and a nucleus. The cell is surrounded by a membrane and so is the nucleus. Inside the nucleus lies a "nucleolus" (nū-klē'ō-lŭs)—or "little nucleus."

By 1838 and 1839 two German scientists, Schleiden (shlī'dĕn) and Schwann (schvän), working together, get the first glimmer of an idea. They find from the microscope that both plants and animals are made of very many tiny cells which are a little like the bricks in the walls of a building. But while bricks are always the same, the cells differ from one another. There are special cells that make up the skin. Other cells make up bone, or hair, or muscle. In the plant, one kind of cell forms leaves, another stems, and still another roots. Yet though these cells seem so different from each other, they are all alike in one thing—they all contain the same jellylike substance which goes around and around inside the cell. This substance is "protoplasm" (prō'tō-plăz'm), which simply means "the first substance." It is the first substance of all, and the most necessary, for when it stops moving the cell dies. And when many cells die, the whole plant or animal dies. At last the secret is out: *it is this living, moving protoplasm that makes us live.*

This living substance is made up of the simple elements that are found in other things. Yet even when we know what it is made of, no one of us can make it, although a good many men have tried hard to do so.

And this remarkable jelly inside each cell can do many of the things that we can do. It takes in food and turns it into protoplasm. It gets rid of the waste materials it does not need. By using the food it takes in, the living jelly grows and grows till it gets so big that its cell divides and makes another cell, its daughter. It moves. "But," you say, "I have never seen a plant move." Yes, you have. You have seen its leaves turn toward the sun.

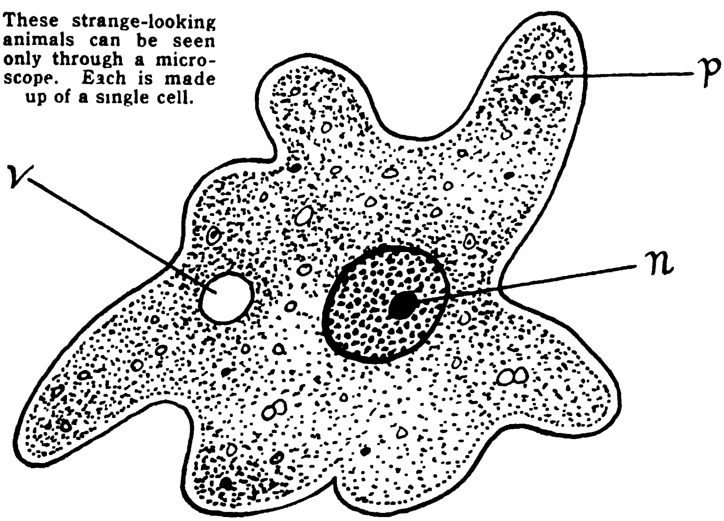
Knowing all these things about protoplasm, Schleiden and Schwann made up an explanation of the way a cell acts and the way a living thing begins. This is the explanation any scientist will give you to-day. It is called the "cell theory." It says that any plant or animal is made up of cells. It may be a single cell or many cells grouped together. But every living creature begins life as a single cell. This cell grows and grows to its largest size. Then it divides into two cells. The two cells grow large and again divide. The four cells divide into eight and the eight into sixteen. And so the cells keep on growing and dividing till they form "tissues"—groups of the same kinds of cells. These in turn form "organs," like the eye, or heart, or stomach. These different organs together make up the "organism," an entire plant or animal. When the cells have divided into the various tissues and organs, the business of the whole organism is more easily carried on, by the division of labor. The eye sees, the feet walk, and the brain thinks, and all the other organs do their own special task. But they all work together.

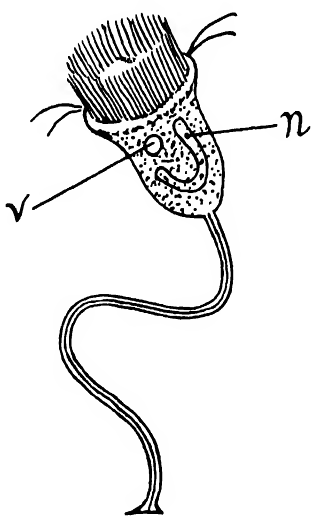
We have all heard the human body called a machine. It is a very wonderful machine, and it works all by itself. It stokes itself, changing food into fuel. It repairs itself by forming new cells when some of its old ones die. It regulates itself. It even thinks about itself, and about many other things. Some of the other animals can do a little thinking, perhaps, but in this a human being is out of all comparison with the rest. He has a wonderful brain with which to think. Man is the only animal who has been able to think enough to find out how his body works—to discover all that we have been saying here. But though he has already found out so much, he still has a great deal to learn.

In some other stories, to come later, we are going to tell about what we know concerning all the important organs of the human body. The brain will be one of them.

But what, you are doubtless asking, makes the protoplasm live and move and digest food and subdivide? *What* is it that makes it alive? To this great question the scientist in his laboratory can give us no answer. He finds it all a mystery!

These strange-looking animals can be seen only through a microscope. Each is made up of a single cell.





The simplest of all animals is the amoeba (à-mē'bà), just above. It is merely a blob of jellylike protolpasm—*p*. It has no fixed shape, but sends out rounded projections called pseudopodia (sū'dō-pō'dĭ-à)—or "false feet"—which are always changing shape. In this way it flows along and surrounds its food. The protoplasm on its surface forms a very thin membrane probably only a few molecules thick. The protoplasm inside—called the cytoplasm (sī'tō-plăz'm)—is granular. It digests the lumps of food the amoeba takes in, and expels the waste through a tiny pore. When too much water collects in the amoeba it is gathered into the contractile vacuole (văk'ū-ōl) at *v*—and expelled through a second pore. Somewhere in the cytoplasm lies the nucleus. When an amoeba grows large the nucleus—at *n*—divides in two and the whole creature splits in two.

The Vorticella, above right, has only one cell, but its outside membrane is firm and the cell keeps its shape. The hairs—or cilia (sĭl'ĭ-à)—at the top have a wavelike motion that creates a whirlpool to draw in food, and the stalk can contract into a corkscrew. A system of tiny canals carries fluids into the contractile vacuole.

Reading Unit No. 2

WHY WE STAND ON OUR FEET

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Things to Think About

Why do people who turn around many times to the left, stagger to the right when they stop turning?

What makes dizzy people imagine that the room is spinning around?

What scientific basis is there for the existence of a "sixth sense"?

What enables us to judge the weight of objects without using a scale?

What kind of people have fine muscle sense?

Picture Hunt

How many semicircular canals have we in each ear? 2–282

In what part of the canals are the sensitive hair cells found? 2–282

What happens to the fluid in an aviator's ear canals when the airplane whirls around? 2–283

What keeps people from becoming dizzy on high places? 2–284

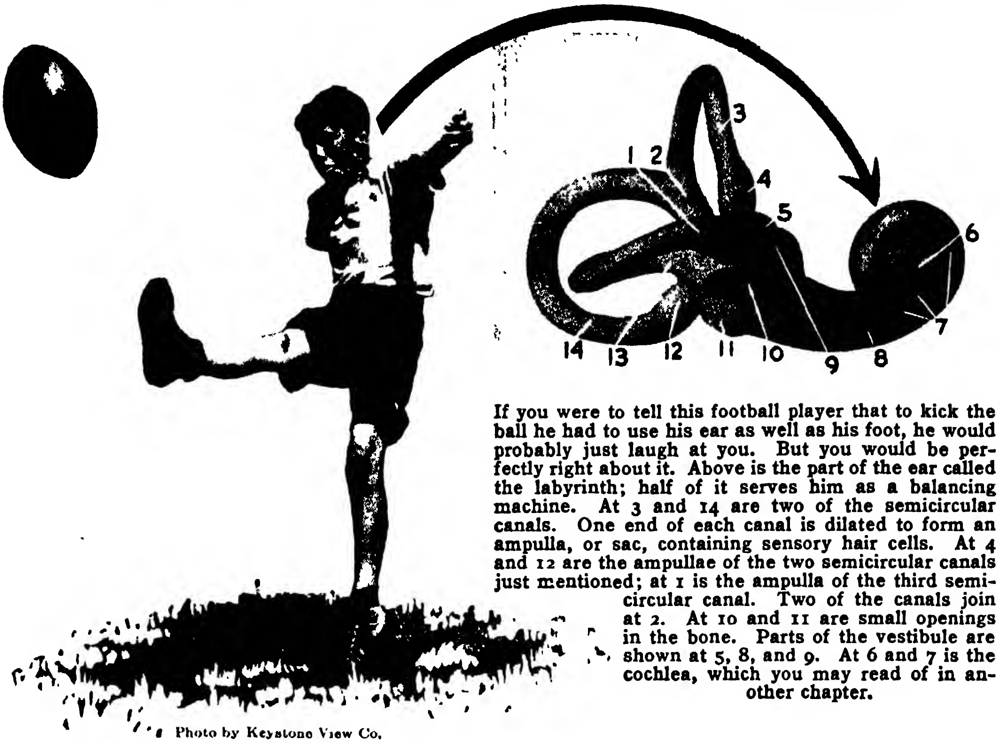
Leisure-time Activities

PROJECT NO. 1: To learn how the semicircular canals act, blindfold yourself and turn rapidly for a few moments in one direction. Stop, and see what happens to you. Do you agree with the conclusions on page 2–283?

PROJECT NO. 2: Do the experiment described on page 2–284.

Summary Statement

Strange as it seems, our ears keep us from getting dizzy, and from falling. They help us to know where we are going and to keep our balance. Semicircular canals in the inner ears are filled with fluid. When we turn or bend, this fluid moves and bends tiny sensitive hairs. These hairs send messages to the brain. The brain causes our muscles to tighten on the side away from the one we bend toward, and so thus to keep us from falling.



If you were to tell this football player that to kick the ball he had to use his ear as well as his foot, he would probably just laugh at you. But you would be perfectly right about it. Above is the part of the ear called the labyrinth; half of it serves him as a balancing machine. At 3 and 14 are two of the semicircular canals. One end of each canal is dilated to form an ampulla, or sac, containing sensory hair cells. At 4 and 12 are the ampullae of the two semicircular canals just mentioned; at 1 is the ampulla of the third semicircular canal. Two of the canals join at 2. At 10 and 11 are small openings in the bone. Parts of the vestibule are shown at 5, 8, and 9. At 6 and 7 is the cochlea, which you may read of in another chapter.

Photo by Keystone View Co.

WHY WE STAND *on* OUR FEET

Do You Know about the Little Canals in Your Ears That Can Keep You from Tumbling, Make You Seasick, and Help You to Be an Aviator?

IF YOU want to be an aviator, a dancer, a sailor, an acrobat, a tight-rope walker, a mountain climber, or a riveter on skyscrapers, you will find it very important to have some good—now what do you suppose?—some good little canals in your ears! You will need a good joint and muscle sense, too, but those tiny "semicircular canals" will make a world of difference. This story will tell you why.

One day a man who wanted to be an airplane pilot walked into a medical office to take his physical examination. The doctor put him into a revolving chair and turned him round and round and round to the left.

After a while the chair was stopped. The man got out and stood up straight and tall.

He was rejected as being unfit.

The trouble was that his semicircular canals did not work properly. If they had, he would have fallen or lurched toward the right.

Half of the delicate inner ear consists of three remarkable semicircular canals. Though they are high up in the ear, they keep us balanced squarely on our feet. They are our rudders or balancing machines. Without them, we should act a little like chickens without heads, twisting and turning in all directions. That is what happens to us when our semicircular canals are injured.

These canals are made of delicate bags. They are so cleverly arranged that no matter how we turn, even with our eyes shut, they can tell us pretty well which way we are going. These canals are shaped like half circles—that is how they get their name—

and are placed in three directions, each making a T with its neighbor. All three, however, lead into the "vestibule," which is made up of two rooms. And all three contain a liquid.

In a bulging part in each canal, and in one spot in each little room, is a tiny mat made of hair cells. The mats in the vestibule are different from the others. They have little knobs of lime lying among the hair cells. These mats are made of the magical nervous tissue in which the tiny nerve fibers come to an end.

When we turn around, or are whirled around, like the man in the chair, a very interesting thing happens. The liquid in the little canals begins to move. It goes in the opposite direction from the way we turn—just like the water in a glass when you whirl the glass around. As the liquid in the canals moves, it bends the hair cells just as running water bends the reeds growing in its stream. Then the nerve endings feel the movement and report it to the brain. Thus we know which way we are going.

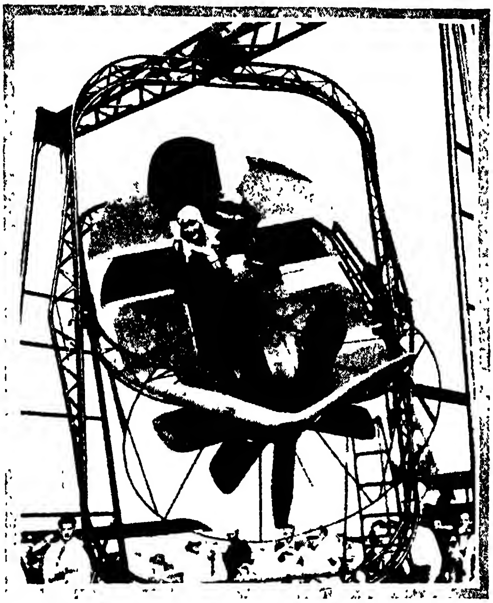


Photo by International News

A would-be pilot can get plenty of thrills without leaving the ground. This interesting machine which can whirl in all directions is used to test a flier's sense of balance.

What Happens When We Nod

When we nod, it is the vestibule that feels the movement up or down. The changed position causes the knobs of lime to press more heavily on some hair cells than on others. The sensitive nerve endings at once send the message of the changed position to the brain. When we go up in a rapid elevator and stop suddenly, it is the vestibule that telephones to the brain, even though we seem to feel the change in the pit of the stomach.

Now suppose you were put into a revolving chair that whirled very, very smoothly, and without any noise at all. And suppose you were blindfolded. If the chair was started quickly you would know it well enough, even if it went so smoothly that you could not feel the slightest jerk; and you would know which way you were going. But suppose you were kept turning for a long, long time, and then somebody asked you which way you were going. You would say, "I'm standing still!"

Then if you were really stopped, you would say, "Now, you're turning me the other way!"

That is exactly what you would say with your eyes blindfolded. For that is what your semicircular canals would tell you.

For when you were first started, to the left for instance, the fluid in the canals would flow to the right. It would tell you that you were going to the left. But as you kept on turning and turning, the fluid would finally catch up with the movement and be at rest. Then it would make you think you were no longer moving at all. But when you stopped, the fluid would keep on flowing to the left, and give you the same feeling you would have if you had actually started to turn to the right. So you would say, "You're turning me the other way!"

If you had had your eyes open all this time, you ought to have felt dizzy. The room would have seemed to be turning toward the right. That is what should have happened to the man in the doctor's office. He should have felt dizzy, and have fallen to the right.

When we spin or waltz around, it is the liquid in the middle pair of semicircular canals—one in each ear—that flows.

In a similar way you can also start the liquid in the other two pairs turning. Drop your chin on your chest and whirl around on your heels. When you stand up straight the

Photo by Photonews Inc., N. Y.

A tight-rope walker? No, indeed—just a workman walking along one of the steel bones of a New York skyscraper in the making. In the circle is a picture of the ear and its parts—one of which, the labyrinth, plays such an important part in keeping this workman from falling from his dizzy perch. Nos. 1 and 3. External auditory meatus, a tube through which sound waves pass. Nos. 2 and 8. External ear. No. 4. Middle ear. Nos. 5 and 7. Semicircular canals and cochlea of internal ear. No. 6. Eustachian tube.

room will seem to be doing cartwheels in front of you.

Hang your head on one shoulder, spin around, and then stop and raise your head. This time the room seems to be turning somersaults over you.

That is what happens inside the ears of an aviator when he "loops the loop" or does "barrel rolls." For this reason, good semicircular canals are necessary for an airplane pilot. But they must not be too good! If they are, he will get dizzy much too soon.

How Our Eyes Help Keep Us Balanced

Of course you know that your eyes help you in keeping your balance. When you do a deep knee bend, you keep your eyes fixed on one spot so that you will not fall. The tight-rope walker does the same thing unless his sense of balance is so perfect that he can walk the rope blindfolded. Even then, he has another sense to help his canals. The sense of touch in the skin of the soles of his feet guides him along the rope.

To walk or run or dance gracefully, some of our muscles must be taut while others must be loose or relaxed. The semicircular canals are responsible for these changes in the muscles! Whenever you move your head in one direction the muscles on the opposite side of the body become taut.

Suppose you were bending over a deep precipice, or leaning out of a very high window. Looking down so far, you would get dizzy, with your eyes telling you one thing about your position, and your feet and semicircular canals telling you another. But before you could have time to think about it, the muscles of your back would stiffen and pull you back out of danger.

That is because there is a regular telephone system of nerves between the muscles and

the semicircular canals over which the messages travel. This system is called a "reflex" (rē'flěks) system. When your finger touches a hot stove and pulls away, that is another "reflex" action. The message from the little nerve endings in your skin travels up over nerves to the spinal cord or the brain, and is "switched" to a motor nerve coming down to your arm muscles; and you pull your hand away without ever having to think about it. It is about the quickest thing you ever do.

Closely connected with the sense of balance is another important sense. It is the famous "sixth sense" that the scientists of our grandfathers' time fought about so bitterly. Some of them said, "There is no such thing as a sixth sense. You're out of your head to say that!" So they fought and fought, until at last the "sixth sense" won. They proved that lying among the ordinary muscle fibers, and at the joints, there are special "muscle spindles" which feel every movement of the body, and can even tell the position of each part when at rest.

We do not have to look at our feet to know whether they are crossed or not. We eat without watching our hands reach our mouths and without slopping the food about. We can swim without ever thinking about what our arms and legs are doing. The muscle spindles around which the nerve endings twine send messages to the brain to tell it exactly what is happening, even in the farthest little toe; and most of the time we do not even give the messages a thought. Only when we happen to think about the little toe do we realize where it is and what it is doing.

The muscle sense is the one that helps us to judge weights. If you merely hold a piece of lead in your hand you cannot tell so very well how much it weighs. But if you "heft" if by moving your hand up and down, you can guess the weight pretty well.

The dancer, the surgeon, and the musician develop the muscle sense to a very high perfection. They learn to make their movements most accurate and precise. The surgeon has to be very careful and exact in his work. The musician can do the most difficult chords and trills without giving them a thought. The dancer has to be highly skilled. And in the dancer this sense of movement is very closely connected with the sense of balance in the semicircular canals. The two senses work together to give the perfect sense of balance which is as necessary to the good dancer for her turns and leaps and balances as it is for an acrobat.

This lad thinks he is balancing himself by means of his long pole; but in reality his semicircular canals are of even greater importance in helping him to perform his difficult feat.

Reading Unit
No. 3

THE SUIT OF ARMOR WE ALL WEAR

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What our skin does for us, 2–287
How the skin is constructed, 2–287-88
Why people's skins get brown in summer, 2–288
Why we have finger prints, 2–289
How hairs, nails, and corns grow, 2–290-91
How our skin helps us to feel, 2–291-92
How our skin regulates body temperature, 2–292-93

Things to Think About

Why is our outer skin constantly falling off?
What causes colored skins?
What causes chapped hands?
How does our skin prevent germs from entering us?
What types of sensation does the skin receive?
Why do we have to sweat?

Picture Hunt

Why do babies cry as soon as they are born? 2–287
Why are finger prints useful in police work? 2–289
What are the pores in the skin? 2–290
What part of your nail is alive? 2–290
What should you do to a needle before you remove a splinter with it? 2–291
How can people shed tears through their noses? 2–292

Related Material

How are crayfish protected from enemies? 3–254-55
How does the hermit crab protect its soft parts? 3–182

Leisure-time Activities

PROJECT NO. 1: Make a survey of sensitive spots on your nose, throat, and chest. Use the point of a toothpick. Also hunt, on the back of your hand, spots sensitive to pain, to heat, and to pressure. Use a pin point. Record the number of each kind of sensation spot. Which spots are more numerous? 2–291-92

Summary Statement

The skin keeps germs out, regulates body heat, lets us feel things, removes certain body poisons, and grows hairs and nails. When we sweat, the water in the sweat evaporates, and so removes heat.

Baby learned to cry at a very early age. In fact, crying was just about the first exercise baby ever took! He cried when he was born because his sensitive skin was feeling the cold for the first time—and he must cry now for a certain length of time every day if his lungs are to develop properly.

Photo by Soibelman Syndicate

The SUIT *of* ARMOR WE ALL WEAR

The Largest Organ of the Body Is the Skin, Which Warns Us of Many a Danger and Wards Off Millions of Invading Enemies

AS SOON as a baby is born, it opens its mouth wide, filling its lungs with air, and begins to cry. If it does not, the doctor spanks it rather hard till it does, for by crying the baby must learn how to breathe. If it never cries it will never live. The baby cries because it feels cold. But as soon as it is wrapped in a soft, warm blanket and its sensitive skin is no longer exposed, it stops crying and falls fast asleep, seemingly glad enough to be alive.

Our skins are almost as sensitive as a baby's. They have to be, for it is partly through our skins that we learn to know the world about us and how to act in it. Our covering of skin separates us and protects us from the outside world. It tells us a great deal about that outside world—that stones are hard, that fire is hot, and a thousand other things. The minute our skin touches anything too hard or too hot, we pull away quickly without thinking, in less time than it takes to wink an eye.

"Beauty," they say, "is only skin deep." But perhaps that is deeper than we think. How deep is the skin?

It is seven layers deep. And in these seven layers are found many different devices for our protection and our beauty. The skin is divided into the "epidermis" (ĕp′ĭ-dûr′mĭs), which means "that which lies upon the skin," and the "dermis" (dûr′mĭs), or "true skin," and the "subcutaneous (sŭb′kû-tā′nē-ŭs) layer," or the layer lying under the true skin. "Dermis" is the Greek word for skin, while "cutis" is the Latin one. The epidermis is made of four layers, the true skin of two, and the subcutaneous layer of one. Altogether, that makes seven layers.

Study the diagrams of the skin carefully. Can you make out the different layers? Notice how flat the cells of the top layer of the epidermis are. They are arranged like the scales of a fish. They are hard, too, like fish scales, but they are much, much smaller. The protoplasm (prō′tô-plăz′m)—that is, the cell substance in a cell of this kind has been changed into a hard material. Such cells,

therefore, are no longer living. This "horny layer," as it is called, is the only one in the whole body made up of dead cells.

"But," I can hear you say, "I thought that when many cells die, the animal dies."

That is exactly what happens in the skin. The cells below the horny layer are always being pushed upward. That is because they keep on growing and dividing. When they reach the outer layer they become flat and full of horny matter. Their protoplasm dies. They remain part of the horny layer for a while. In this way they protect the skin underneath. Then other cells are pushed upward and the horny outer cells are just cast off from the skin. Like old, discarded clothing, they are no longer useful. Other cells have taken their place and do their work. We have all seen little bunches of these discarded cells, especially after bathing, in little flakes of skin that have peeled off.

Photo by Clay-Adams Co., Inc

These two cross sections show you the three main layers of the skin. Above to the left is a view of the skin on your finger, and above to the right is a view of the scalp. Between the epidermis and the subcutaneous tissue is the layer called the "true skin," derma, or corium. It is full of nerves and blood vessels.

The Last Layer of Skin

The two layers directly underneath the horny one are harder to make out. We can see, however, that their cells are not so flat as those above them. In fact, the farther inside the cells are, the less tightly are they packed. So when the last layer of the epidermis is reached, the cells are easy to make out. This last layer, the "rete Malpighii" (rē'tê măl-pĭg'ĭ-ī), is the most important layer of the epidermis. It was named for Malpighi (măl-pē'gē), an Italian university professor who lived at the time of Leeuwenhoek (lā'vĕn-hŏŏk), the man who made the microscope. Malpighi was the first man to make out the rete under his crude little microscope, as well as the first to describe it. The rete lies directly on the little hills and valleys formed by the true skin, dipping down into each valley and rising on top of each hill. It is attached firmly to the true skin, like grass to the soil, by little "prickles" from its cells which bury themselves deep in the tissue of the true skin.

Inside the cells of the rete are many little color bodies, or pigment bodies, which give the color or complexion to our skins. Fair people have few color bodies, dark people have more, and Negroes have a great many. In Negroes, in fact, the color bodies are found all the way up to the cells of the horny layer. And what do you think would happen if a piece of skin from a white man were grafted to the skin of a Negro? It would turn black. And if a piece of Indian's skin were attached to a white man, the Indian's skin would turn white.

This pigment protects us from the too-strong glare of the sun. In summer some of us get a nut-brown tan, while others blister and burn, and still others freckle. When the skin feels the bright, hot sun on it, the rete immediately sends out a call for more color bodies so that it may act as a brown sunshade to the true skin underneath. Very fair people have not many color bodies in their skin and blood. They have to use real sunshades, or else they blister and burn just as if they had touched something hot. A blister forms whenever water from the body gets between the rete and the layer above. Though you would hardly think it, a blister is really meant for a protection. The water makes a soft cushion to keep the true skin from being hurt further before more color bodies can come to protect it. When these color bodies put more pigment in one spot than they do in another, freckles are made. Freckles and real sunshades are not half so pleasant as an even coat of tan. You are lucky if you can get one early in the season.

Photo by Federal Bureau of Investigation

When the police have a man's finger prints on file, they know that they have the best possible means of identifying him later, for no two finger prints are ever exactly alike. Above is a young visitor at the office of the Federal Bureau of Investigation in Washington having her finger prints taken for the bureau's files.

So the epidermis is the protective layer of the skin. The true skin contains most of the delicate structures: the sweat glands, which are simple coiled tubes that manufacture sweat; the hairs in their little pits, or follicles (fŏl'ĭ-k'l), and with their special muscles beside them; and the little fat glands which keep the skin and the hairs well oiled.

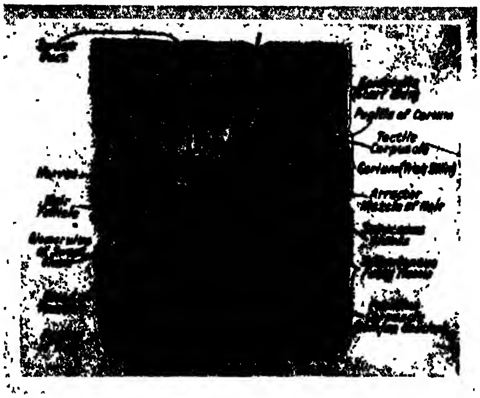
These fat glands are important. Without them we should be in a very bad way. How should you like to have a skin that looked like an alligator's? There are a few unlucky children born that way, for that is what happens when the oil glands are out of order and do not work properly. These oil glands keep our skins smooth and pliable. If the oil glands do not work well, the skin gets hard and rough and scaly. It "chaps."

This is a "close-up" of a finger print. If you will look closely at one of your own fingers you will see little ridges and whirls rather like these. But they cannot be exactly like these; the pattern will always be different.

The true skin, as you know, is not quite smooth on top, but forms a network of little hills and valleys. It is these ridges which make finger prints. Though the cells are always changing, the pattern of the ridges remains exactly the same throughout life, and no two people ever have the same finger prints. In these ridges, or "papillae" (pă-pĭl'ē), as they are called, are found important and delicate structures of the skin. In some papillae there are little blood vessels which bring water and food to the skin, and take away its wastes. Other papillae contain tiny nerve endings which are even more wonderfully and deli-

cately constructed than a radio set. They are the telegraph offices or the receiving stations of the body. And each hair, too, has a tiny little papilla at the bottom of its little pit from which it grows.

The spaces between the structures of the skin are filled with a network that looks like tangled thread intertwined with tiny rubber bands. This is the "connective tissue" which makes our skin so elastic and strong. See how much it can stretch when you lift the skin on the back of your hand. But there is a limit to all things. If the skin has been stretched too much, it will form wrinkles. This happens especially to old people, in whose skin there is more elastic tissue than fibrous tissue—as the white, threadlike connective tissue is called. Wrinkles also appear when the fat cells in the little pouches in the subcutaneous layer are used up, for the skin fits loosely and wrinkles over the muscles, instead of fitting tightly like a glove.



Did you ever stop to think what happens to your skin when you cut yourself?—of the many, many tiny devices that must mend and get well again after they have been damaged? This cross section through the skin shows you these neat contrivances —of course many times larger than they actually are.

From what we have been saying, you can see that the skin is made of many different tissues. Therefore it is an "organ." And if you ever go to a medical school you must not let the professor catch you when he asks, "What is the largest organ in the body?" It is the skin!

Did you know that the hair and nails, and even horns, are made from the skin? They are formed in exactly the same way as the horny layer. Their cells are pushed upward from below. They become flattened like fish scales and filled with horny substance. They are dead.

In this picture parts of the nail and of the fold of skin which covers its root have been removed to show you how a nail is made. That part of the finger or toe on which the under surface of the nail rests is called the "nail bed" (2 and 7). Along this run longitudinal—or up-and-down—ridges (1). The nail itself has several parts: the sharp "margin," or free end; the nail "body" (3); the "moon"—which is almost covered by a fold of skin called the "nail wall" (4 and 6). The nail grows from the root (5), where it fits into a groove in the skin beneath the nail wall.

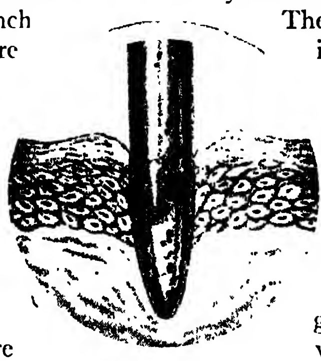
As you can see, there are three kinds of hair: the tiny hairs that grow all over our bodies, except on the palms, soles, and lips; the middle-sized hair of the eyebrows and lashes; and the long hair on our heads. There are color bodies in the hair, just as there are in the skin—and the color of the hair has a good deal to do with the number of hairs on a head. Blond people have the most hair, and red-haired people the least. If you are blond you may have about 140,000 hairs on your scalp—a very great number. If your hair is brown or black, you you will have about 109,000; and if your hair is red, you will have only some 90,000.

The color bodies are found in the central, hollow canal of each hair and in the long, delicate, scalelike cells in the body of each hair. When there are no more color bodies in a hair, it turns white. Sometimes hair turns white even when there is pigment present. You remember how, in the story of "Les Misérables" by Victor Hugo, Jean Valjean's hair became perfectly white in one hour. He had to save a man who was sentenced to prison for the crimes that he himself had done. He did not want to, but his conscience made him, and in that hour when he was deciding whether or not to do right his hair turned white. In some unknown way his worry made air spaces form in the body of the hair. These air spaces do not allow the color in the central canal to show through, and so the hair looks white.

Each hair grows from a special little bulb at the base of its special pocket in the skin; and each hair, curly or straight, grows only

when cells are added to it from the little bulb at its base, for then it is pushed upward. After a hair grows for a while, its bulb starts to form a new hair which pushes the old one out so far that it falls away.

Nails grow in the same way as the hair; the flattened cells are pushed up from below. A nail grows about $\frac{1}{32}$ of an inch a week. In Shanghai, China, there was a priest whose finger nails were $22\frac{3}{4}$ inches long. How long did it take him to grow them? Twenty-seven years. Like the hair, the nails also form air spaces between their cells. These make the white spots we get in our nails when we bang them.



A very thoughtless person is pushing a needle into his skin to remove a splinter. This is what the needle and skin look like under a microscope. The needle point is covered with germs, for our thoughtless friend forgot to disinfect the needle before using it.

In man, the hair and nails are not so important as the same sort of structures seen in the claws, hoofs, scales, and fur of the lower animals. These are the animals' chief means of protection and warmth. Man has learned to make shoes and clothing. He has learned to make tools. He uses his nails in working delicately with his finger tips, never for scratching in the earth; and his hair as a beautiful adornment. To keep the hair healthy and the nails useful, care is necessary. The hair should be brushed daily in order to stimulate the growing cells at the roots, and washed often enough to clean away the dirt and dead skin which we know as "dandruff." The nails should be kept clean, short, and unbroken; and the skin around them should be pushed back often in order to avoid hangnails.

What Causes a Corn?

Sometimes, but very rarely, certain cells in the horny layer begin to grow and grow for no reason at all. They form horns exactly like the horns of animals. Corns and calluses are a little like horns. They are hard, and usually form when the cells of the horny layer are constantly rubbed, as when corns form on the toes where the shoe pinches or rubs. They hurt a great deal because the hardened cells press down on the delicate skin underneath. The thing to do is to get something to relieve the pressure of the shoe and to be sure next time to get shoes that are big enough but not too big.

The skin protects us only when it is whole and unbroken. It acts like a strong suit of waterproof armor against which the invading army of dirt and germs is usually powerless. Their poisonous shafts strike against it and fall off, harmless. Sometimes the strong armor of the skin is pierced—by a pin prick, a cut, an insect bite—and then it is advisable to wash the smitten place immediately and to disinfect it. Thus the enemy is killed before he enters the body and grows deadly. "An ounce of prevention is worth a pound of cure," especially when we are dealing with disease germs! We should wash often. We can never tell when our good armor may be broken. We should always keep it clean, free from dirt and germs. The danger of infection is then lessened. The little oil gland pores are places of easy entrance for dirt. If the skin is not kept clean, the dirt gets in and forms the ugly blackheads we all know and dislike.

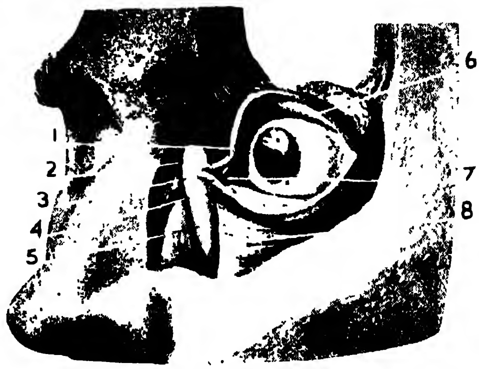
The skin is not like an ordinary suit of armor. It lets sunlight enter into the body and work changes there. Direct sunshine is healthful. It helps to cure many diseases, such as various kinds of tuberculosis and rickets, a disease in which the bones of children remain soft. Sunlight increases health and strength. That is why sun baths and open-air swimming are so popular in our day.

Unlike any other armor, the skin has feeling. The nerve endings in their little papillae, or hilly nests, are the devices through which we feel. They are the receiving stations that pick up messages by direct contact with the outside world. There are many different kinds of feeling in the skin. There is the feeling of touch, which is strongest in the finger tips and lips. You know how a blind man can almost see with his finger tips. Then there is the feeling of pain. The feeling of pressure tells us whether a thing is hard

or soft. Finally, there are the feelings of heat and cold. We can tell when a thing is hot or cold only because we have special nerve endings that act as weather bureaus, one kind for hot, and the other for cold. So altogether there are five kinds of feeling in the skin alone—to help protect us from harm.

If a tiny cinder touches the white part of the eye it hurts terribly, while if that same little cinder falls on the hand it is hardly felt at all. The eye is so very delicate that if the cinder gets farther inside, it will be dangerous, and might even cause blindness. So it is well that the eyeball is very, very full of little S.O.S. stations, the nerve endings of pain, which feel the presence of the slightest particle of dust. They immediately send out calls for help. The eye begins to water and the invading particle is probably washed away in a flood of tears.

Even in other parts of the skin there is a great difference in sensitiveness. For there are more sense stations in some spots than in others, just as there are many more receiving stations in a city than there are in a sparsely settled country. The skin of the throat and face is much more sensitive than that of the chest and head because it has many more sense stations, or sense spots of pressure, grouped close together. Try it and see. See how much harder you can press a toothpick on the skin of the chest without its hurting than on the throat or the tip of the nose. The delicate organs of the chest and head are incased in bone boxes, and the head, besides, is well covered with hair which protects it. They need less warning of danger and injury than do the more exposed parts of the throat, with its important blood vessels.



From this picture you may learn what happens when you cry. Part of the upper face has been removed in this model to give a general view of the lacrimal apparatus—the apparatus which has to do with tears. The spongelike little mass showing above the upper eyelid is the superior lacrimal gland, one of the two glands where tears are manufactured in order to keep the eye moist and comfortable. The tears are emptied into the eye through small ducts (6), and are conducted away from the eye through small canals (3) that have their openings at the inner corners of the eyelids (1 and 4). You can see these openings with the naked eye. These canals carry the tears to the lacrimal sac (2), which at its lower end passes into the nasal duct (5); this duct opens into the nose. Oil glands are contained in the little pink lump (7) at the corner of the eye. At 8 is a muscle. Of course, when a great many tears pour into the eye, they overflow the lids.

As you know, there are more S.O.S. stations of pain in the eye than anywhere else. The largest number of hot and cold spots are found in the nose, and of pressure and touch points in the tip of the tongue. Even the short hairs all over the body help in our sense of touch. Touch the tip of a tiny hair and see if you do not feel a tickle. Sometimes, because the sense spots are so close together in the skin, two or more senses combine to give a single feeling. When we have a feeling of wetness, we are using the senses of hot or of cold, and of touch.

Besides telling us so many things, the skin is a heat regulator. The body must be kept at a certain temperature. When it gets too warm, the skin cools it by giving off heat. When it gets too cold, the skin stops giving off so much heat. The skin does this in two ways: by the evaporation of the water that comes from the sweat glands, and by the sending out of heat from the warm body directly to the cooler air outside.

How the Skin Is Cooled

When it is hot, sense stations of heat send messages to the nerve endings which control the little blood vessels of the skin. These nerve endings immediately stop working—it is their duty to keep the blood vessels at a certain small size—and the blood vessels dilate (dī′lāt), or grow larger. The blood rushes in, for there is more room for it, and the skin becomes flushed. You have seen how red people get when they are too warm. The blood is being cooled by giving off its heat directly to the air.

When a person is cold the opposite thing happens. The weather bureaus of cold send

messages to the same nerve endings, directing the blood vessels to work harder. They make the blood vessels so small that the blood is pushed out of them, deeper into the body. That is why, in cold weather, one's skin looks pale and blue—there is so little blood in it. In order to send the blood even deeper, all the little muscles in the skin, especially those around the hairs, contract, making little bumps. This is the "goose flesh" we get when we are very cold. Later on, even though it is cold, the skin gets red again. The little blood vessels get tired and stop work. They relax. Make a fist as tight as you can, and see how quickly you get tired. It is much easier to relax your hand. That is what happens to the little blood vessels. The nerve endings can no longer control them. They simply will not work.

What Makes Us Perspire?

We lose heat directly to the air only when our bodies are warmer than the surrounding air; when the air is hotter than our bodies, we lose our heat by the evaporation of sweat. When water evaporates from anything—from a wet dress hanging on a clothesline or from a sidewalk after rain—the surface of the object becomes cooler. Some of the heat is used up in changing the liquid water into water vapor. That is exactly what happens to our bodies. The skin contains many little sweat glands. A gland is a little manufacturing plant producing a certain substance. When we are hot, these sweat glands get messages to produce more sweat, which is mainly water taken up from the blood. As the water evaporates the skin gives off its heat and we grow cooler. That is why hot weather is not so bad when it is dry as when it is damp. For the air can take up only a certain amount of moisture. When it is damp, it already has a large amount of water vapor, and so the sweat is not evaporated from the skin, but remains on it, leaving us sticky and uncomfortable. In cold weather, on the other hand, the skin stops producing sweat in such large quantities, and since very little is evaporated the skin keeps its heat.

The sweat glands average producing as much as two pounds of water every day. It is the duty of the sweat to throw off some of the waste products of the body with its water. That is another reason for keeping the skin clean by washing thoroughly and often. Otherwise, this waste remains on the skin, where it clogs up the fat-gland pores until they form blackheads, and the sweat-gland pores until they can no longer work properly. This is a story people tell about what can happen to the skin if the pores are clogged up for too long:

It was at the time of Italy's greatest splendor, when some of the greatest painters the world has ever known were living. The populace of Rome was seething with excitement. For weeks it had waited for a grand event. Travelers from all over the world had come to see the greatest man of the powerful family of the Medici (mĕd'ē-chē) made Pope Leo X.

The Danger of Painting Our Bodies

People in colorful holiday clothes lined the streets in great numbers. The procession began! First came the forty cardinals in their brilliant red robes, with the new pope in their midst. The people bowed their heads. Then, behind them, in a beautiful carriage drawn by four white horses, came an angel, a child so beautiful that people shouted and laughed with joy to see him. His whole body was painted with gold, his wings were gold. The sun shone brightly on him, making a halo about him so that he looked like an angel from Heaven.

That night he died. The gold paint, either because it had clogged his pores or because it had contained some bronze alloy which is poisonous to the skin, had killed him.

Few if any of us are ever going to wear gold paint. But there are many other things nearly as bad which we ought to keep off our precious skins.

Reading Unit No. 4

WHY WE NEED TWO EYES

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The story of the six blind men and the elephant, 2–295
Why the eye is like a camera, 2–296
How your eye is built, 2–296-99
How light affects the retina, 2–298-300
What happens when we look at moving pictures, 2 300
Why we need two eyes, 2–300
How we focus our eyes on objects, 2–300

Things to Think About

How do blind men "see" our world?
In what way is each eye specialized?
How may the eye be compared with a camera?
What enables your eyes to see things near and far?
Why can cats see better in the dark than we?
What is meant by "color blindness"?

Picture Hunt

Compare parts of the eye with your camera, 2–296-97
What opening lies in front of the lens of the eye? 2–296
How does the retina "see" an object? 2–297
How many muscles move each eye? 2–298, also color plate opposite 2–278
Why is the eye placed in a bony frame? 2–298, also color plate opposite 2–278
What keeps our eyes from filling with tears every few minutes? 2–299
How does the brain get messages from the eye? 2–300

Related Material

How did Helen Keller overcome the handicap of being deaf, dumb, and blind? 12-567-68
How does a fly "see"? 3–273
What happens to your eyes when you cry? 2–292

Leisure-time Activities

PROJECT NO. 1: Make a large chart of the eye for your school, 2–296.
PROJECT NO. 2: Study a camera with a ground-glass back in order to see how objects look when seen through a lens, 2–297.

Summary Statement

The eye has a clear cornea, a hole in the iris called the "pupil," through which light passes, and a clear lens to bend the rays; then, a very sensitive layer, the retina, which is able to send messages to the brain through the optic nerves.

Did you ever stop to think how quickly our eyes take in the whole size and shape of things? Suppose you had to feel an elephant to find out its shape? Would you do any better than these six blind beggars who thought the beast like anything from a wall to a snake, according as they happened to touch one part of him or another?

WHY WE NEED TWO EYES

Do You Know How the Cameras in Your Head Manage to Give You a Continuous Moving Picture of All Outdoors?

ONCE upon a time there were six blind men who sat and begged every day by the roadside. As they sat they talked of what they thought the world was like and of the animals in it.

"I have never felt an elephant," said one.

"Nor have I," said the other five. "What is it like, I wonder?"

Then one day there was a great "to-do" on the roadside. An elephant was passing by!

"Let us feel of your elephant," begged one of the blind men of the driver.

"Surely," answered the driver, and the beggars proceeded to do so.

"Ah!" said the first, as he reached up and touched the huge side of the elephant, "an elephant is exactly like a wall!"

"No, indeed," said the second, as he felt the tusk, "an elephant isn't like a wall at all. It is long and smooth and sharp. It is like a spear."

The third beggar, meanwhile, had seized one of the elephant's legs. "An elephant is round and tall like a tree," he said.

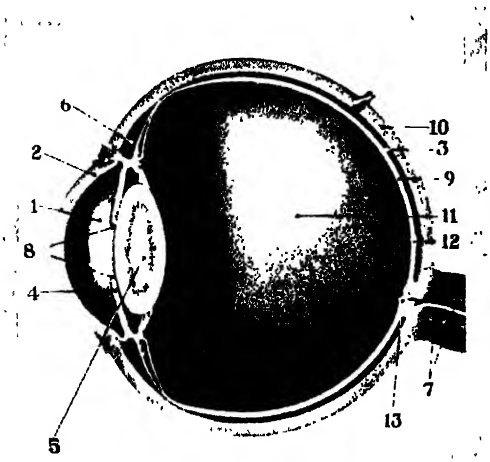
The fourth grasped the trunk, and cried, "He is long and he is round, but he wriggles from side to side, and up and down. He is like a snake."

The fifth man was very tall. He reached so high that he easily touched the elephant's ear. "You are all mistaken," he said, "an elephant is like a huge fan."

The sixth blind beggar, who was very old, had barely time to reach the elephant before it moved on. He grasped the tail. "You are all wrong," he shouted. "An elephant is not like a wall, a tree, a spear, nor a snake; neither is it like a fan. It is exactly like a rope!"

The elephant passed on, but the six blind beggars continued to quarrel all day as they sat by the roadside.

If we had no senses, we should be even worse off than these six blind men. In no way at all could we tell what the world was like. We could not smell or see or taste or hear or touch. We should not even be able to stand up straight, for—though most of us do not know it—there is a special sense that



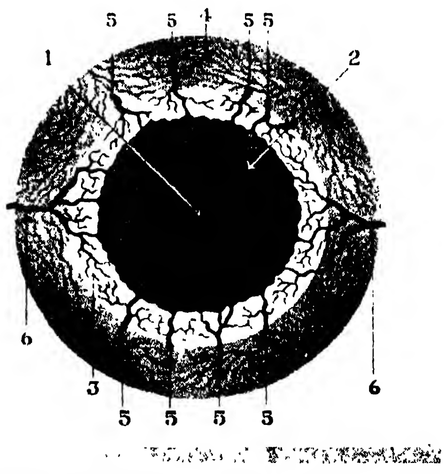
Here is a diagram of the eye in lengthwise section, to show the different parts described in this story. It shows the two compartments of the eye—the frent (1) filled with aqueous humor, the back (11) with vitreous humor; the cornea (2), iris (4), pupil (8), lens (5), and ciliary muscles (6); the three layers of the eyeball—sclera (10), choroid (3), and retina (9); and the optic nerve (7). The blind spot is at 13 and the yellow spot at 12.

keeps us balanced squarely on our feet, and not on our heads, like Old Father William in "Alice in Wonderland." Without our senses we should know absolutely nothing. We should die.

These senses work in a marvelous way In another story we have told how in the skin there are very special "spots" for the different kinds of feeling. Some spots with their nerve endings are sensitive only to cold, others only to heat, and so on. The other sense organs, as they are called, work in the same way. The eye is sensitive to those vibrations in the ether that we call light, the ear to the vibrations in the air that we call sound. We smell only when little chemical particles in the air touch the special cells in the nose, and we taste when the food particles touch the special cells in the tongue. We cannot hear with our noses or smell with our eyes because each sense has a special end organ, or "receptor," through which it works —and it has no other. Each receiving station of the senses has its special nerve that carries its special message to the brain. And it is the brain that really sees the picture or smells the odor or hears the sound.

A camera is made up of a strong black box that lets light in at only one spot, the lens. The opening for the lens can be made bigger or smaller by a curtain that photographers call the "diaphragm" (dī'ȧ-frăm). In the rear of the box is a sensitive film on which the light is focused through the lens so that it makes a picture. You know how the photographer pushes the camera box back and forth till he gets the object he is photographing clear and well focused.

Now, our eyes are cameras more perfect than the photographer's. They need no sensitive films to be put into them. They have a sensitive film that never wears out. It is called the "retina" (rĕt'ĭ-nȧ). Our eyes do not have to be focused. They focus them-



This is the eyeball from in front. 1. Pupil. 2. Iris. 3. Ciliary muscle. 4. Choroid. 5, 6. Ciliary arteries.

selves. In fact, our eyes work entirely by themselves, and even better than the most complicated camera.

The whole eyeball acts as the box of the camera. It is made of strong connective tissue, like the connective tissue in the skin. This is called the "sclera" (sklē'rȧ). We see the sclera as the "white of the eye." In the very center, where it is transparent, it is called the "cornea" (kôr'nē-ȧ). Inside this

When rays of light are focused in a lens and then passed on to make an image on a screen, they cross and make the image upside down. But when this happens in our eye the brain interprets the image as right side up, for when we were very tiny we began to learn the true positions of things.

strong layer there is a thin dark layer, like the black coat of paint inside the camera box; this is called the "choroid (kō'roid) coat." Part of this choroid coat extends somewhat over the lens of the eye. Here, it is the colored part of the eye we call the "iris." Just as with the hair and skin, when the iris contains a great number of color bodies the eye is dark brown; when it contains few, the eye is blue. The very dark spot in our eyes, the "pupil," is the round window through which the light enters, going through the lens to strike the sensitive film, the retina. The pupil is dark because the eye is black inside. The retina is the thin, delicate layer just inside the dark choroid coat. To keep the eye in shape, the eyeball contains a transparent jellylike liquid that allows the light to pass through it easily. In front of the lens, this liquid is called the "aqueous (ăk'wē-ŭs) humor"—or "water fluid"; behind the lens, it is called the "vitreous (vĭt'rē-ŭs) humor"—or "glassy fluid."

As we have said, the eye works like a camera. The light from objects is focused by the lens very clearly on the retina. There are tiny muscles inside the eyeball that are attached at one end to the lens by a tiny cord, and at the other end, by little strings or fibers, to the choroid coat. These muscles change the shape of the lens. When the muscles contract they pull at their fibers attached to the choroid coat and so loosen the cords attached to the lens, which then bulges. When the muscles stop pulling, the strings tighten, and the lens again becomes flattened. In this way the eye can see things near and far. For the little muscles, all of their own accord, change the shape of the lens so that it focuses the light clearly on the retina.

As you see, the lens is elastic. In old people it loses its elasticity and no matter

how hard the little muscles pull, the lens will not bulge much, but remains flat. The flattened lens focuses objects on the retina better when they are at a distance than when they are near. That is why old people are far-sighted. They can see things that are far away better than those that are near.

The iris is a muscle that works in such a way as to let just the right amount of light enter the eye. You must have often noticed how small the pupil becomes when a person comes from a dark room out into the bright sunshine. You have seen, too, how large and round a cat's pupils are at night, and what narrow little slits they are in the daytime. Because the pupils are so large at night, the tiniest glimmer of light can enter and cats can see in what we call "the dark." The iris, by closing or opening over the lens, makes the pupil larger or smaller.

The eye lies in a cavity of the skull called the orbital cavity, one side of which is here shown cut away so that we may see the eyeball (3) in relation to the muscles that move it. There are six of these muscles, four of which can be seen in our picture. Four of the six are called "recti," or straight muscles, and two "obliqui," or oblique muscles. The superior rectus, or upper straight muscle (2), turns the eyeball upward; the inferior rectus (7) turns it downward; the recti on the side (4) turn it sideways. All these muscles come together at the back of the eye (5), where the optic nerve is. The oblique muscles (10) help pull the cornea inward. Part of another muscle is also shown (1); it moves the eyelid. The walls of the cavity are formed by bones of the skull (6); 8 and 9 are the canal leading in the direction of the ear region, and the opening to it; 11 is the inner edge of the orbital cavity in front; 12 is the cornea.

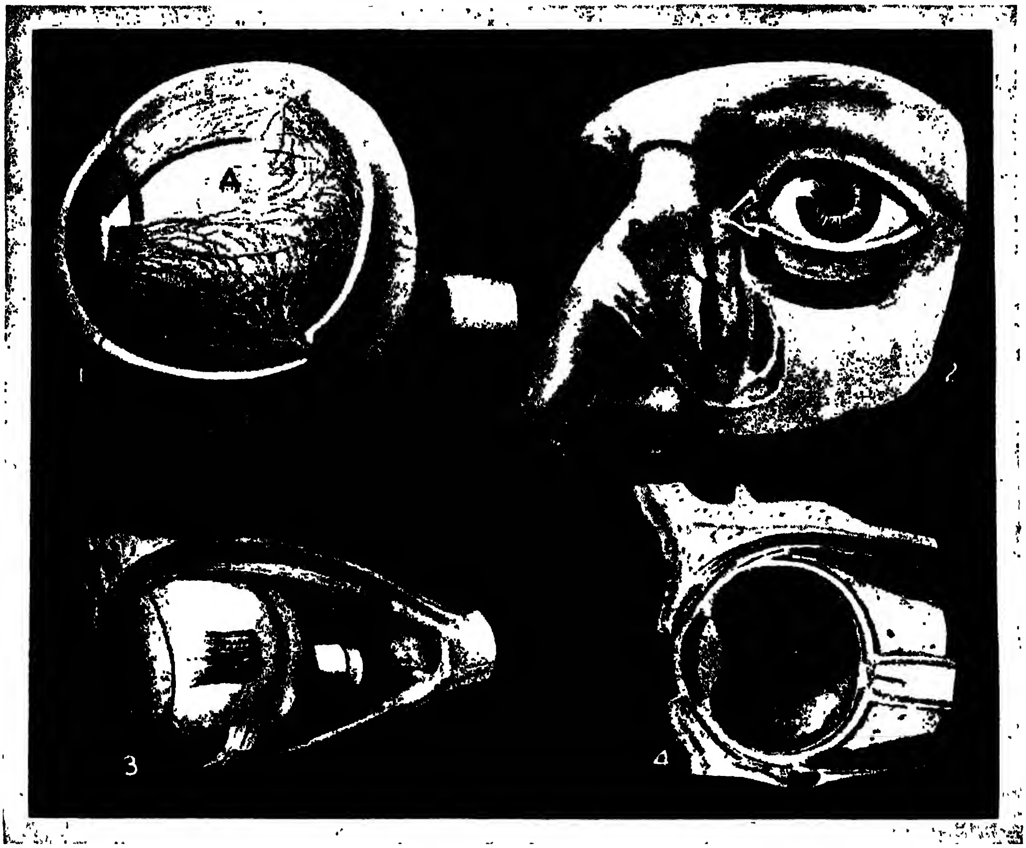
The retina, the sensitive film of the eye, is the most wonderful part of the organ. It is made of ten layers of "nervous" tissue—that is, of the same kind of material as the magic organ of the brain. The most important part of the retina, however, is the layer of special cells on which the light acts directly to make them work. They are not found in the front layer of the retina, where you would expect them, but in the back, right next to the dark choroid coat. The light goes through all the layers of the retina, therefore, before it reaches them and sets them to work. It is lucky that the retina, in spite of its many layers, is so thin and delicate and transparent.

These cells are called "rods" and "cones" because they look exactly like these things. There are four times as many rods as cones. But the cones are more important. Along the outer edges of the retina, near the lens, there are very few cones and many rods, but in the center of the retina, in the middle of a little pit called the "yellow spot" on account of its color, there are only cones.

Really, we know very little about how light acts on the rods and cones of the retina to make us see. They become active and they transfer their activity, electrically we think, through the nerve fibers to the brain. The theory is that the rods and cones act "photochemically," in the same general way as does the "sensitized" film of a camera, whose substance is bleached or changed chemically by the action of light. The rods and cones have the power, however, of getting new material from the choroid coat when their substance is used up. A film cannot do that. Another part of the explanation is that the cones are used for bright light and for color, and the rods for dim light. The rods contain a substance called "visual purple"—it is deep red—which helps us to see in dim light. One reason why cats see better than we in the dark is that their rods contain much more "visual purple."

The center of the yellow spot is made up only of cones. It is with this spot that we see most distinctly. We use it when we read print and when we try to distinguish objects very clearly.

But though this spot sees so clearly in the



Photos by Clay-Adams, Inc.

1. This figure shows the eyeball—with cornea at the left and optic nerve at the right—cut to show the three layers of its wall. The outer, thicker layer is the sclera; the second, covered with a network of nerves and blood vessels, is the choroid; the inner (A) is the sensitive retina. 2. Tears are secreted from a gland above the eye, and drain off through the forked tubes shown here into the tear sac (B), which connects with the nose. 3. In this figure we can see how the eyelid, at the left, lies down over the cornea; the nearer side muscle has been cut away and the optic nerve cut through so that we can see the muscle on the farther side. 4. This is a general view of the eye in its socket. The lid, optic nerve, muscles, and cornea you will recognize from other figures. Within the eyeball itself, the lozenge-shaped body is the lens. The thin curtains at the left of the lens are the iris, with the opening of the pupil between them. To the left of that is the front, or anterior, cavity; to the right of the lens is the back, or posterior, cavity.

daytime, it is blind at night because it contains none of the rods that we use in dim light. Astronomers know this. They never look directly at a faint star, but a little to one side; in that way they do not use this central spot, but the outer edges of the retina where there are many rods present. Some night you might try it for yourself. Go out and look at the "Big Dipper." First look at the handle directly to see if you can distinguish the faint star next to the second bright one. If you do not, look a little to one side, and see if it will not come into view.

We cannot see colors in dim light, though many people do not realize the fact. In the twilight, red is often matched with navy blue. There are some people, most of them men, who are "color-blind" all the time. Green and red simply are not green and red to them, but gray. We do not know the reason for this. John Dalton was the first person known to be color-blind. He could not understand why people thought the sight of red cherries on a green tree was beautiful. It all looked dull and gray to him. One day he went out to shop. He came back wearing a pair of "scarlet silk hose." His Quaker relatives were horrified. John Dalton had mistaken them for dark brown.

In these days of red and green traffic and

signal lights color blindness is dangerous. Many tests have been devised to discover the defect before men are allowed to qualify as drivers or engineers.

An interesting thing about the sense of sight is that the pictures we see remain with us even after we stop looking at them. That is what happens when we look at moving pictures. While the wheel is turning we still keep on seeing what went just before, and so we see the many, many separate pictures of the film as one "continuous" moving picture.

Sometimes the "picture memories" we see change color. If you look steadily at a green object and then look at a piece of white paper you will see the object on the paper as red. Black and white work the same way. If you will glance at some of the pictures that go with this story, you can see some of the tricks your eyes will play.

This figure shows the eyeballs and optic nerves of a child looked at from above; all the muscles and other surrounding parts have been removed. 1, 6. Bones inclosing the orbital cavity. 2, 5. Left and right eyeballs. 3, 4. Bony structure of the nose. 7, 11. Right and left optic nerves. 9. Optic chiasma, where some of the optic nerve fibers cross on their way to the brain. 8, 10. The nerve bundles along which sight travels onward to the brain.

What We Can See with One Eye

In 1793, in France, a little baby girl was born with only one eye in the center of her forehead. She saw perfectly, except that everything looked flat like the painted scenes in a theater. This is what would happen to us if we had only one eye. Two eyes make solid things look solid. We focus our eyes on one object at a time, but each eye sees a little more of one side of the object than of the other side. You may test this very easily. Look steadily at something. Then close one eye and look at it. Do the same with the other eye. Do you see how the object seems to change its position, and how you see more of one side with one eye, and more of the other side with the other eye? Because we see the "sides" of things, they have "depth" for us. With only one eye they would all look flat.

In order to focus both eyes on a single object each eyeball has three sets of muscles. These correspond to the wheels of the photographer's camera which he moves around to get a good focus. Otherwise any time we wanted to see an object clearly—with the yellow spot—we should have to move our heads, a very troublesome process. As it is, the muscles of the eyeball move the eye. Some of us can even "roll" our eyes, so active are our muscles.

When the muscles of the eyeball do not work well together, one pulling harder than the other on the opposite side, the eyes cannot be focused on one object properly, and the person sees a thing double. He is "cross-eyed." Through experience, the cross-eyed person learns to use only one eye, and thus he sees each object only once.

As you can well understand, the eye is a very delicate instrument. The least injury may be fatal and cause blindness. The eye has to be well protected, and it is. The eyelids, lashes, and eyebrows are the sentinels that keep the enemy—dust—away. The cornea and "white of the eye" have many little sense spots of pain that send messages to the brain to start the tear glands working when any dust gets past the sentinels. These remove the dust by drowning it out with their tears.

The tear glands are inside the upper and lower eyelids at the point farthest from the nose. When they start working the eye fills and overflows. The eye has even a drainage system which collects some of the extra water and empties it into the nose.

Reading Unit
No. 5

HOW THE EAR HEARS A NOISE

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How we hear, 2-303-5
How sound waves affect the ear bones in the head, 2-303-4
How a tube protects our eardrum from air pressure, 2-304-5
How deep mines and tunnels affect our eardrums, 2-304
How loud noises may result in deafness, 2-304
How the inner ear translates sound waves into hearing, 2-305

Things to Think About

What enables an animal to "gather in" sounds?
How does an eardrum send its vibrations to the inner ear?
Why is there an open tube connecting the middle ear with the throat?
Why do our eardrums feel pressed in when we ride in a tunnel?
What do men do to prevent deafness when they fire a cannon?
How can we hear the most complicated music?

Picture Hunt

What do sound waves have to do to the ear before your brain translates them into words, music, or noises? 2-303
What makes the eardrum vibrate? 2-303
Why are the important parts of the ear inside the skull? 2-304
How is the sense of balance dependent upon the ear? 2-304

Related Material

Why would you hear no sounds on the moon? 1-138
How do we know that air has pressure? 1-452-56

Leisure-time Activities

PROJECT NO. 1: Make a large chart of the way the human ear works, 2-303.

PROJECT NO. 2: To learn how the Eustachian tube affects the eardrum, breathe in deeply, then close your mouth and nostrils, and try to blow gently through the stopped-up nose. Can you feel the eardrums popping out? Do not blow too hard or you may injure the ears, 2-304.

Summary Statement

The real ear begins with the delicate eardrum which vibrates when sound waves hit it. This drum sets the middle-ear drums vibrating, then the inner-ear drums, and then the fluid in the cochlea, which has sensitive nerves that lead to the brain, where the real "hearing" occurs.

Photo by Anderson, Rome

This is how Midas got his ass's ears—they were given to him because his own ears were so faulty that he preferred the pipes of Pan to the divine music of Apollo's lyre. You may read the whole story below.

HOW *the* EAR HEARS *a* NOISE

If There Were No Ear to "Listen In," Niagara Might Tumble Forever without Causing Any Roar at All

HAVE you ever heard the story of the conceited old god Pan, who had learned to play so well on his pipes that he thought he could make sweeter sounds than even Apollo, the god of music?

One day while he was wandering in the woods with his friend Midas, he met Apollo and challenged him to a test of skill. "I play so beautifully that the wind in the reeds, the bees on the bells of the thyme, the birds in the bushes, the nymphs and the fauns, all become silent. You are jealous of my piping, O Apollo! I dare you to compare your skill with mine!"

Apollo, very angry, accepted the rude challenge at once.

Tmolus (tmō'lŭs), the mountain god, was chosen judge. He sat down and cleared away the trees from his ears to listen. Then he gave the signal and Pan began to blow on his pipes. The conceited god was very much pleased with his piping, but Tmolus turned toward Apollo, and all his trees turned with him. Then Apollo took up his lyre. When he struck the strings, Tmolus at once gave him the victory.

But Midas did not agree with the award. "Why," he said, "do you not hear that Pan's pipes make sweeter music than Apollo's lyre?"

"Your ears are depraved," answered Apollo. "In order that you may hear better henceforth, your ears shall be those of an ass."

And so it was.

But do you know why an ass or a dog or a horse can hear better than a man? One of the main reasons is that he can move his ears.

This diagram shows very clearly the path of sound waves through the canal of the outer ear, the drum, the three little bones, and the cochlea, and then off by way of the auditory nerve to the busy brain.

Of course you have noticed how a dog or a horse will cock his ears at a sound. He does it to catch the sound waves—the vibrations in the air—better. A man cannot do that. To be sure, there are a few people who can wriggle their ears a little; but most of us have lost the power. We have to turn our whole heads. Dogs and horses can locate sounds better than we can because they know exactly in what direction they have to move their ears to hear the sound best.

The Advantage of Having Two Ears

With two ears we can locate sounds much better than with only one. If a noise sounds louder in the right ear than in the left, we know that it is coming from the right, and not from the left. Of course our eyes help us in all this. If we hear the drone of an airplane and look up in the general direction of the sound, our eyes soon tell us exactly where the sound is coming from. But very few of us can tell exactly where a cricket is when we hear it chirping, or just where a motor truck is from its rumble alone.

The ear is made up of the "outer," the "middle," and the "inner ear." The outer ear consists of the part we usually think of as "the ear," and of a long narrow tube which is hollowed out of the hard bone of the head. These parts, together, form a kind of trumpet. But of course people who are talking to us do not often speak straight into the trumpet. They may be some distance away, they may have their backs to us, or be somewhere upstairs. What they do is to blow sound waves into the air; and when these sound waves reach the trumpet, we hear a noise!

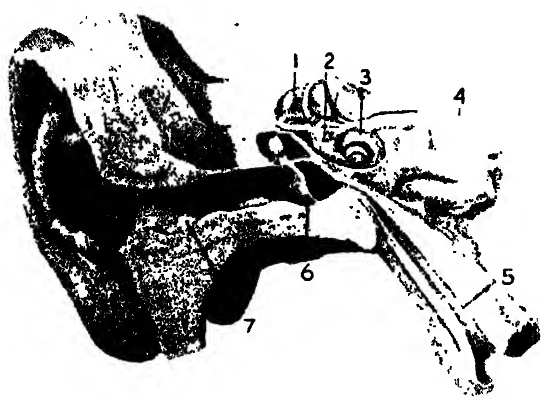
The sounds go through the trumpet and strike on a drum. The middle ear is called the eardrum. It is a very unusual drum, however, and has a number of features that ordinary drums do not have. Instead of having the same covering of skin on both sides, it has one large covering on the outer side, called the "tympanic (tĭm-păn′ĭk) membrane" or "drumhead," and on the inner side two little window-shaped holes covered by skin and separated by a great deal of bone. These covered openings are called the "oval window" and the "round window."

The Hammer, the Anvil, and the Stirrup

Then there are three little bones that are attached from the middle of the drumhead, on the one side, to the oval window, on the other. These bones are called the hammer, the anvil, and the stirrup, because they look very much like those objects. The hammer has two handles. The shortest is attached to the drumhead, while the head of the hammer seems to bang right down on the anvil. The anvil is attached to the stirrup, which in turn is joined to the oval window.

Now when anyone speaks to us, or when any other sound reaches our ears, the sound waves, or vibrations in the air, strike on the drumhead and move it up and down. When the drumhead moves, it moves the handle

of the hammer with it. The hammer then beats on the anvil, and the anvil moves the stirrup. When the stirrup moves, it acts on the cover of the oval window, which thus also vibrates. The vibrations that have come through the trumpet of the outer ear to strike on the eardrum, go on through it with the help of these three little bones, and reach the inner ear—which is the part that really "hears." And instead of being weaker and fainter after their journey through the outer and middle ear, the vibrations are stronger than before. They have been intensified by the action of the three little bones.



Here we have the most important parts of the ear shown in diagram and labeled: 1. Semicircular canals, which give us our sense of balance. 2. Vestibule of the inner ear. 3. Cochlea. 4. Auditory nerve. 5. Eustachian tube. 6. Eardrum. 7. Outer air passage or canal.

In the eardrum there are two tiny muscles. One is attached to the drumhead, the other to the stirrup. When the muscles contract, they tighten the drumhead and the covering of the oval window. This makes the vibrations stronger, just as happens when we tighten the skin of a real drum. When we listen very carefully to faint sounds or to a sound that is far away, it is these little muscles that help us to hear them.

Why Our Ears Close in a Tunnel

From the middle ear there is a tube that runs right through the hard bone of the head and opens into the throat. This Eustachian (ū-stā'kĭ-ăn) tube, as it is called, from the name of the man who discovered it, has a little lid on it at the throat end. This lid is usually kept closed; it is opened only when we swallow or yawn. As we swallow, we let air into our throats, and some of it goes through the open door of the Eustachian tube all the way up into the eardrum. This air is very important. It keeps the pressure of the air on the inside of the drumhead the same as the pressure on the outside. And because the air pressure is the same on both sides, the drumhead is kept from caving in and breaking.

Sometimes the air pressure on the outside is greater than usual as in deep caves and mines, or in tunnels where compressed air is used. There we soon know we need more air in our Eustachian tubes. To get it, we make many swallowing movements or give a hearty yawn. The next time you ride through a deep tunnel under water, you may notice a little pressure or a little ringing in your ears. That will be because the drumheads are being pushed inward, since the air outside is heavier and pushing harder than the air inside. If you do not like it, swallow a few times, or give a good yawn.

Why a Pistol Shot May Cause Deafness

You may remember how, in "The Tale of Two Cities," the last sound that Miss Pross ever heard was the report of the pistol fired close to her when she was wrestling for dear life. The force of the shot was so great that it burst her eardrums, and she became deaf. You must never fire a gun right behind a person's head, and never let him fire one behind yours. Men who handle cannon know about the force of their big guns. They hold their mouths open to allow plenty of air to enter and keep their eardrums from being shattered.

You have seen how a bad cold will sometimes make a person deaf for a while. That is because the Eustachian tubes become so stuffed and swollen that the air cannot

go through. Then the drumheads cannot vibrate well. Such deafness may be cured by blowing air into the tubes till the accumulations in it are pushed out.

What Happens When We Hear a Sound

The inner ear is very delicate in shape. It is made of two separate parts, both tunneled out of the hard bone of the head. Only one part is used in hearing. This is called the "cochlea" (kŏk'lē-ȧ), and is shaped like a snail's shell. It is filled with fluid instead of air. The vibrations tapping on the outside of the oval window cause the fluid in the inner ear to vibrate, just as your hand swished back and forth in water makes it move in waves. The waves in the ear flow all the way up into the tip of the snail shell and come down again on the other side till they reach the round window. As the waves pass upward they strike against a very special bag that fills the middle part of the shell almost to the tip.

This bag - very much like a balloon filled with water allows the vibrations to move its own fluid in the same way. Here, inside the bag, or "cochlear canal," the first step in the process of hearing takes place. Here the air waves which traveled through the air till they struck the drumhead, and passed through the three little bones of the middle ear, and then changed into the water waves of the inner ear, at last are turned into the sound that we hear.

But before we can understand how the water waves in the little bag can change into sounds, we must know a little more about what the men learned in physics, as well as the physiologists, have to say about sound and hearing:

Now anything can be made to vibrate, if you can only find the right note to set it in motion. If you take a slender piece of string and hold it fairly tight before your mouth with both hands and then sing a note, the string will vibrate, or move from side to side—that is, it will do so if the air waves of your note move at the same rate, or speed, as the vibrations or movements set up in your piece of string. Try it and see.

And what happens when a conductor tunes his orchestra? The pianist strikes the note C, and all the 'cellists and violinists immediately begin to tune their instruments to get the same note. They can do this because the C strings in the piano, when the piano note is struck, at once begin to move, just as the piece of string did. All the musician has to do then is to tighten or loosen his own string to get the note exactly right.

If you will sing into a piano which has its strings exposed and its loud pedal down, you will see that the string corresponding to your note will begin to move. And that, as the physicists and physiologists think, is what happens inside the little bag in the cochlea to make us hear.

Turning Vibrations into Sound

The cochlear canal contains the little piece of machinery that changes the water vibrations into sound. It consists of a floor made of many little fibers stretched from side to side along the whole length of the bag. In fact, the floor makes one of the bag's sides. On it rests a tunnel formed by two rows of rod-shaped cells. On the inner side of the tunnel a single row of delicate hair-tipped cells extends all the way along, while on the outside there are five rows of hair cells. These hair-tipped cells are special sensory cells in which the delicate nerve fibers from the brain end. When the fluid inside the bag vibrates, the fibers of the floor, or the hair-tipped cells—we are not sure which—act just like the strings of a piano. They vibrate when the vibrations go at their rate. Somehow, no one really knows how, these vibrations are changed into nervous energy which travels through the nerves to the brain; and then we hear!

Each part of the cochlear canal "hears" sounds of a different pitch. The fibers at the tip of the snail shell answer to low notes which have a slow rate of vibration. Those at its base answer to high notes, whose movements are very fast. Many different fibers may vibrate at the same time. In this way the most complicated music can be heard and enjoyed.

Reading Unit No. 6

WHY YOU CANNOT TASTE COFFEE

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How the sense of taste depends on the sense of smell, 2–307
The four tastes, 2–307
Why the tongue must be kept wet, 2–307-8
How we smell things, 2–308
How odors are classified, 2–309
Why we stop smelling certain odors, 2–309
How our senses of taste and smell may save our lives, 2–309

Things to Think About

Why do foods seem tasteless and odorless when we have a cold in the nose?
How are taste buds in the tongue able to tell you what is in your mouth?
Why do people sniff deeply when smelling a flower?
Why can people stay in an ill-smelling room without noticing it?
How do we know that the sense of smell is keen?
How does the sense of smell influence our choice of food?

Picture Hunt

Why does modern man need a keen nose if he is to enjoy life? 2 307
In what structures are taste buds found? 2–308
What part of the tongue is movable? 2–308
How does the brain get messages from taste buds? 2–309

Related Material

How are hunting dogs able to follow an invisible trail even in a snowstorm? 4–501
How are blind ants able to find their way to the ant hill again? 2–392

Leisure-time Activities

PROJECT NO. 1: To test your dog's sense of smell, hide yourself completely from your dog near your house and then whistle for him.
PROJECT NO. 2: To learn how we taste things, try a lump of sugar on a dry tongue. Wait until your mouth waters. What is necessary to make the sense of taste operative? 2–308

Summary Statement

The sense of taste depends on the sense of smell. With a stuffed or dry nose most foods lose their taste. A dry tongue also prevents one from tasting food. Substances must be dissolved before they can be tasted or smelled. That is why the nasal passages and tongue must be kept moist.

Courtesy Standard Oil Co. (N. J.), photo by Hubley

We rarely think how much we should miss if we had no sense of smell. Civilized man relies much more on eyes and ears and less on his nose than his ancient forefathers did. So he finds it easy to forget that without his nose he would miss the fine flavor of food and a flower's delicate fragrance.

WHY YOU CANNOT TASTE COFFEE

What You Really Do Is to Smell It, as You Will See from All That Is Said Here about Taste and Smell

WHAT we commonly call taste is not really taste at all. It is smell! With your nose stuffed, apple tastes like onion, and savory sausage like bread. But what a difference with the nose free and active! Then we "get" the flavor of foods, because their odors reach the nose through a back door by way of the throat and other rear passages. It is the savory odor of food that gives it what we call a "taste" and makes it delicious.

To the physiologist taste is something much simpler. It is the effect produced by chemical substances on the tongue. There are only four tastes: sweet, sour, bitter, and salt.

Each taste has its special part of the tongue where it is most active. Sweets are tasted by the front of the tongue, sour by the sides and front. Children suck their candy and ice cream with the tips of their tongues. We all sip lemonade there, too. Salt is tasted all over the tongue.

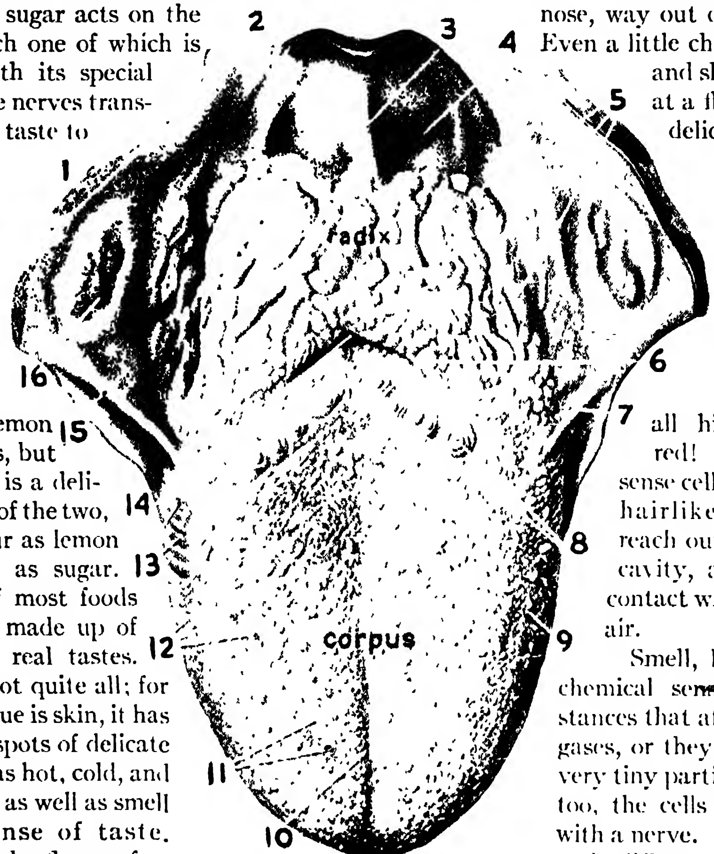
Bitter things are tasted only by the back. For that reason you ought to be able to take a bitter pill without grumbling, and without tasting it. Simply place the nasty thing at the tip of the tongue, or just under the tip, and then swallow it with a quick gulp of water so that it can hardly touch the back. But you have probably discovered this for yourself.

The "tasters" of the tongue are oval bodies called "taste buds" distributed all over the surface of the tongue. They are made of the important "sense cells" with which the nerve endings are also connected. Like most other sense cells they are hair cells.

Each taste bud is located in a little pit out of which the "hair" sticks. Foods, or other substances to be tasted, must be dis-

solved in liquid. You can test this fact for yourself. Dry the tip of your tongue well by breathing with your mouth open, and then put a lump of sugar on it. You cannot taste the sugar till your mouth waters. Then the dissolved sugar acts on the hair cells, each one of which is connected with its special nerve, and the nerves transmit the sweet taste to the brain.

We all know that lemonade does not taste so sweet as its sugar in some sips, nor so sour as its lemon juice in others, but that its taste is a delicious mixture of the two, neither so sour as lemon nor so sweet as sugar. The tastes of most foods are "blends" made up of two or more real tastes. And that is not quite all; for since the tongue is skin, it has the different spots of delicate feeling, such as hot, cold, and touch. These as well as smell help the sense of taste.



This picture shows the upper side of the tongue when it is removed entire from the mouth. "Radix" means root, and "corpus" means body; the freely moving tip of the tongue is called the apex. 1. Edge of the arch between the pharynx and soft palate. 2, 3, 4. Folds and hollows connecting the tongue with the epiglottis, the lid which keeps food from "going down the wrong way." 5. Lingual tonsil, or tongue tonsil, which is spread around on the root. 6. Groove between root and body. 7, 15. Fold or arch where the tongue passes into the soft palate. 8, 9, 11, 12, 13. Different shapes of papillae, the little nobs on the surface of the tongue; certain of them contain taste buds. 10. Crease down the middle of the tongue. 14. Point where the root and body meet.

So what is the flavor of lemonade made of? It is made of sweet, sour, cold, and lemon odor. The taste of strawberry jelly is made of sweet, of strawberry odor, and of touch—for its smoothness is part of the taste. And now see if you can tell what makes up the taste of hot roast beef!

In many of the animals the sense of smell is far stronger than in man. If a dog is given a piece of old clothing he can actually hunt out the person to whom it belonged, just by the odor! But on the other hand, if a stranger wears his master's clothes, the dog may trust him for a while. A dog would not say "Seeing is believing," but "Smelling is believing."

In us, as in dogs, the sense cells of smell are located safely in the upper part of the nose, way out of harm's way. Even a little child knows this, and she sniffs deeply at a flower to get its delicate scent.

The sense cells lie in a layer of other cells that are all yellow. That may seem strange to anyone who thinks all his insides are red! As usual, the sense cells have delicate hairlike tips which reach out into the nose cavity, and come into contact with the odorous air.

Smell, like taste, is a chemical sense. The substances that affect it must be gases, or they must be very, very tiny particles. As usual, too, the cells are connected with a nerve. But this nerve is different from those in some of the other sense cells. It grows right out of the cell! It is part of the sense cell, though it extends through the bone into the brain.

Just as the scientists have separated tastes into only four real kinds, they have tried to separate the odors. That has been much more difficult—so difficult that the only thing the scientists have all agreed on is that odors are pleasant or unpleasant.

Yet the odors are easier to understand if we divide them up. We may use Professor

Woodworth's classification. When you notice how close some of the odors in his list are to one another—the flowery to the fruity and the resinous to the scorched—you will see why it is so difficult to group them. According to Professor Woodworth and some other scientists, there are six real odors:

1. Spicy; like pepper, cloves, and nutmeg.
2. Flowery; like roses or any other flowers.
3. Fruity; like the odor of apple or orange oil, or vinegar.
4. Resinous; like the smell of turpentine or pine needles.
5. Sour; like hydrogen sulphide (hī'drō-jĕn sŭl'fīd), which smells like rotten eggs.
6. Scorched, like the smell of tarry things.

Just like tastes, these smells blend together in a thousand different ways. The smell of peppermint is made of fruity and spicy odors; that of roasted coffee combines the resinous and the scorched.

When you first go into a stuffy room, you smell its stale air and you want to open a window. If you stay there for a while you may no longer notice the staleness. Then another person will come in and want a window open. The reason why you no longer are uncomfortable is that the sense cells are quickly tired by any one odor, though they immediately smell a new one. If the person who came in wore a tiny bit of perfume, for instance, you would easily smell it. The sense of smell gets tired and stops working much faster than any of our other senses.

The sense of smell is very delicate. You can realize that fact when you know that the odor of musk can be detected when dissolved in eight million times as much air, and that the drug called mercaptan (mēr-kăp'tăn) can be diluted twenty-five billion times and still keep an odor that one may detect.

Our senses are our guides. For ages they had the duty of locating food and announcing danger. Taste and smell are the sentinels that guard our bodies from poisons. When food smells bad, we had better leave it alone, and when it tastes unnatural, we had better spit it out.

Photo by General Biological Supply House

This is a cross section of the tongue many times enlarged, of course. At the top, along the surface of the tongue, are shown the little pits that contain the taste buds. Connected with the taste buds are nerves which carry messages to the brain.

Reading Unit No. 7

YOU NEED NEVER LOSE A TOOTH

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How teeth are able to build a healthy body, 2–311-12
How speech defects may arise from poor teeth, 2–312
Why we must keep our teeth clean, 2–312
How mouth breathers and thumb suckers may affect their appearance for life, 2–312
How animals acquired teeth, 2–312-14
How a tooth is made by the body, 2–315
Why baby teeth are hollow, 2–315
How to keep your teeth healthy, 2–316

Things to Think About

What are teeth supposed to do for the body?
Why may bacteria grow in the mouth?
How would you prevent a child from sucking its thumb?
How did the scales of sharks finally become teeth?
What happens in a child's gums when he is "teething"?
Why is it desirable to clean the teeth after each meal?

Picture Hunt

What habit should babies be prevented from forming? 2–312
When does a child start to develop second teeth? 2–313
What additional teeth may high-school students expect? 2–313
How is a tooth fed? 2–313
Which teeth are best suited for chewing? 2–314
What part of a tooth must be kept free from scratches or breaks? 2–315

Related Material

What vitamin helps to keep our teeth from decaying? 2–363
What do we know about bacteria and the harm they may do? 2–12-19

Leisure-time Activities

PROJECT NO. 1: Using a mirror, count the number of teeth in your mouth. How many kinds have you? 2–314.

PROJECT NO. 2: Make a large wall chart of a cross section of a tooth, 2–313.

Summary Statement

Teeth bite and chew food so that we may better digest it. To grow and keep good teeth, we should eat raw vegetables and fruit and never fail to keep the teeth clean. Twice a year, the dentist should go over the teeth.

You may guess from the smile on this youngster's face that he has discovered how easy, and even amusing, it is to give one's teeth a good brisk brushing. He certainly does it at least twice a day, and probably four times, for he knows that is best. He keeps his tooth brush clean and aired, and always buys the tooth paste or powder that his dentist recommends.

Photo by H Armstrong Roberts

Our smiling youngster knows other things about taking care of his teeth besides how to brush them. He would never think, for instance, of running the chance of cracking the enamel by biting on nut shells or other hard things. As a reward, he probably never has a toothache, and goes to the dentist only at the regular times—probably twice a year—just to make sure that all is well.

YOU NEED NEVER LOSE *a* TOOTH

That Is What the Dentists Promise You, if You Will Do Exactly What They Say

THE sisters of Cinderella were ugly and bad tempered and spoiled. One of them sucked her thumb, and the other her fingers. They munched candies and sweets between meals. They would have nothing but the softest and most delicate food, and they always bolted it. They ate only the very whitest wheaten bread. To Cinderella, in her corner by the hearth, they threw the hard crusts and the toughest pieces of left-over food. And she, poor thing, was glad to get them. She chewed and chewed and chewed at them.

And yet she grew more beautiful and they more ugly. Certain doctors assure us that the one who sucked her thumb got "buck teeth" and an overhanging lip. Her nose turned up. The one who sucked her fingers got a protruding jaw. She looked very stubborn and mulish. They both had decayed teeth. The lower part of their faces grew narrow, and their complexions turned sallow. They whined and lisped.

Cinderella's teeth remained like pearls Her skin was lovely. Her cheeks grew round and firm, her profile delicate as a cameo Her voice was like a bell, clear and resonant So when the prince came, he loved her for her beautiful face and lovely voice, as well as for her tiny foot.

The secret of her beauty, as well as the moral of this tale, is that she chewed and chewed and chewed her tough food. And this is truer than most fairy stories, as you can find out for yourself.

The teeth are the pearly gates of our bodies. They cut and break up the food we choose to eat, and get it ready for the stomach and intestines, which continue to prepare it for the use of the millions and millions of hungry cells in our bodies. If the teeth do their work well, the body is

more likely to remain healthy, and if the body is healthy, the teeth are more likely to remain strong.

But the chewing of the food does even more than that, as we hinted in the story of the haughty sisters. When people chew their food, they develop the muscles of their faces, as well as their jaws and their mouths. The arch of the teeth—the bone under the gums where the teeth fit—ought to grow wide enough to let all the teeth come in straight and even as a row of pearls, instead of crooked and uneven, or on top of one another. The roof of the mouth is also wide and well developed, so that the tones of the voice may be resonant. Singers and speakers with beautiful voices know this. When the teeth are too uneven, they let the air out in the wrong places and so the person may lisp when he talks. He may have to have his teeth straightened by the dentist to cure him.

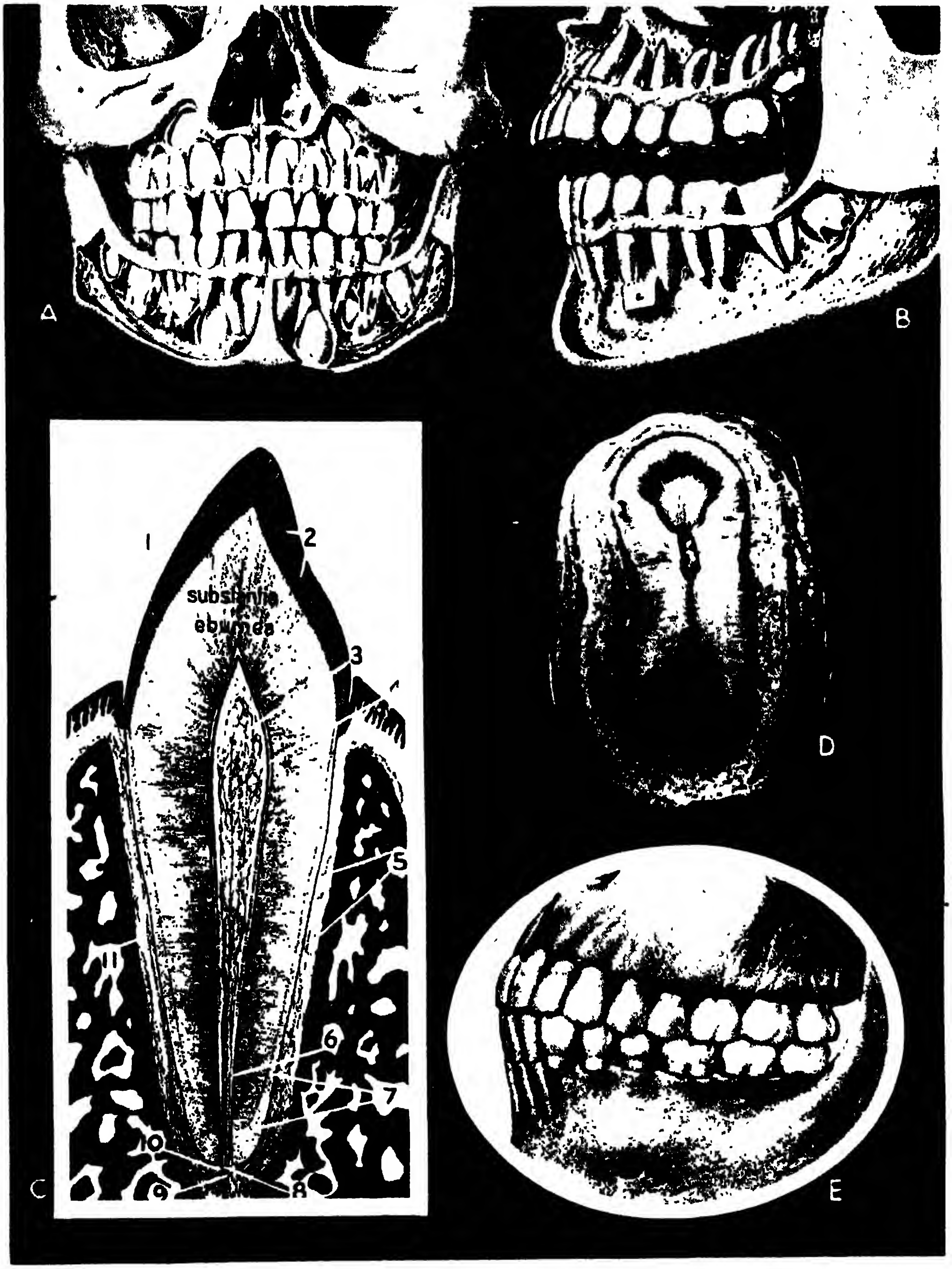
Photo by E. R. Squibb & Sons

Babies find a great deal of satisfaction in sucking a finger or thumb. We are told that it consoles them in their griefs and comforts them when they are tired. Especially, this is true when their gums are swollen and sore from new teeth that are just pushing through.

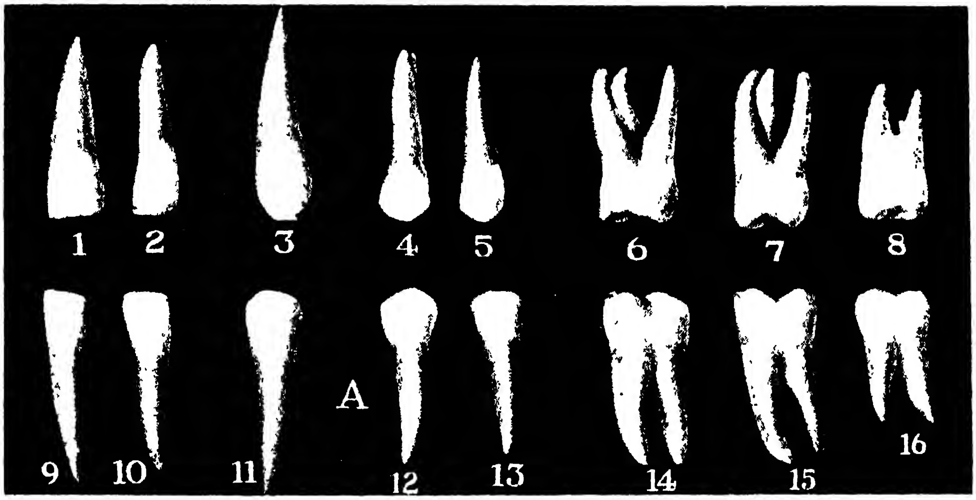
You know that the mouth has no delicate hairs or hair cells to filter the incoming air, as the nose has. The dust, with its tiny bacteria (băk-tē′rĭ-ȧ) and microbe riders, can fly right through. But some of the bacteria, knowing a good berth when they find it, decide to stay on in the mouth. They lodge under the gums and between the teeth, where there are always bits of food to eat, unless the person cleans his teeth carefully at least twice a day. Here they grow and multiply, and form big colonies that eat and eat, until they undermine the tooth itself, and it decays.

Breathing through the mouth injures the teeth in another way, the way in which finger sucking spoiled the faces of the bad sisters, and made them even uglier. When the mouth is closed, the pressure of the cheek muscles on the teeth and gums from the outside is the same as the pressure of the muscles of the tongue from the inside. This helps to keep the teeth straight and even. But if the mouth is always open, there is no pressure on the inside, and the outside muscles press the gums and teeth in, sometimes even to the point of forming a "weak chin." Finger sucking works in the same way. If a child always sucks at his thumb, he always pulls at his upper front teeth, till the whole upper jaw protrudes. If he sucks his fingers, he pulls at the lower jaw till it juts out. Wash your hands, and see for yourself! The horrible rubber nipples that some silly mothers let their babies suck all day long, besides holding thousands of germs, do what mouth breathing does. They make the jaws small and narrow, so that the teeth have a hard time coming in properly.

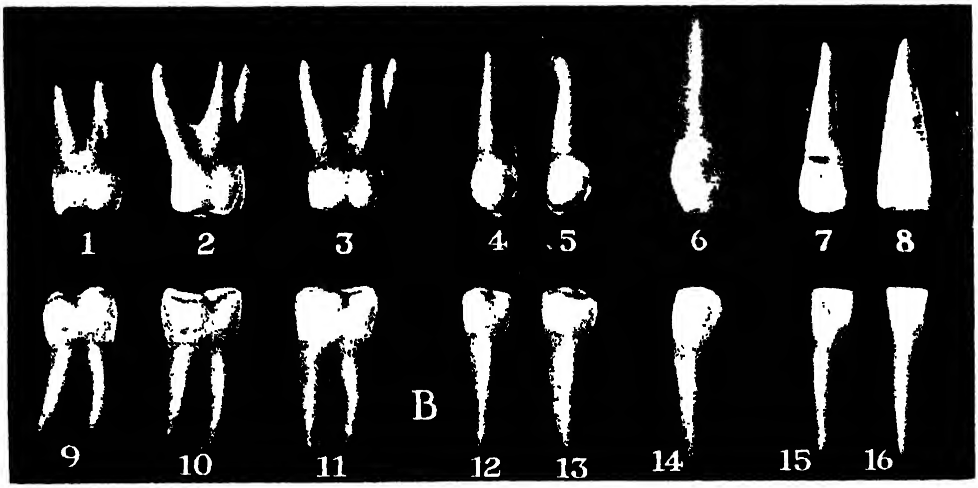
Trillions and trillions of years ago, the scale-covered skin of the shark and the dogfish turned inward around the mouth and formed a sawlike edge, a strainer to hold food. Through long practice at crunching shellfish, these scales developed into teeth. Millions of years later, in other animals, these first teeth were developed into rows and rows of cones along the edges of the jaws. Then, when the different animals changed their homes and had to learn to eat new kinds of food, the jaws and the teeth changed also. The jaws became shorter and stronger, in order to bite better. Some of the teeth—those in front—became sharp. Others became pointed. In the back of the mouth, these simple teeth joined together to form larger teeth with three or four roots. Thus, the teeth became "specialized" to fit the life of the different animals. The teeth of a cow who chews her cud all day are not at all like the teeth of a tiger, who tears his prey apart in a few minutes. Teeth of vari-



A. Skull of a five-year-old child, showing milk teeth and permanent teeth crowding them out. B. Jaws of a person twenty years old; all the milk teeth are gone and all the permanent teeth have come through except the "wisdom teeth." C. Cross section of a human tooth. "Substantia eburnea" is a scientific way of saying dentine. 1. Crown of tooth. 2. Enamel. 3. Pulp chamber. 4. Dentine-producing cells. 5. Wall of tooth socket. 6, 8. Canal and opening for nerve and blood vessels. 7. Cementum. 9. Blood vessel. 10. Nerve. D. X-ray of a thin horizontal section of a tooth. E. Normal position of teeth with jaws closed.



Above (A) are the teeth as seen from the side toward the lips and cheeks; below (B), as seen from the side toward the tongue. These are the names of the teeth in the upper jaw: A1 and 2, B8 and 7. Incisors. A3, B6. Canines. A4 and 5, B5 and 4. Bicuspids, or premolars. A6, 7, and 8, B3, 2, and 1. Molars. Here are those in the lower jaw: A9 and 10, B16 and 15. Incisors. A11, B14. Canines. A12 and 13, B13 and 12. Premolars. A14, 15, and 16, B11, 10, and 9. Molars. This accounts for half of each jaw.



ous kinds developed for crunching or for munching or for grinding the food as much as possible. The long teeth especially—those next to the sharp ones in front—changed into many different forms. They turned into the tusks of the elephant and the walrus, the saber tooth of a kind of tiger who lived long ago, and the double-curved tusks of the babirussa pig, who hangs himself by these handy hoops to the branches of trees; and they turned into the fang teeth of the wolf. And always the teeth became fewer and fewer. But to make up for this loss, they now came in two sets, the "milk teeth" and the permanent set; and in some creatures they came in many sets.

You may have seen a baby teething. First the two lower front teeth peep through, then the upper, then the lower side teeth, and again the upper, till all twenty teeth are out. Usually the baby is about two years old before he has "cut" all his "milk teeth." But

tooth forming is just as complicated as bone building—for teeth are bone—and a great deal more goes on in baby's mouth than you suspect.

First of all, long before the teeth come through the gums, armies of workers, the wandering bone-building cells, have started on their job. The enamel builders, which form the outside of the teeth, line up in position like a row of engineers, with their band of helpers behind them to supply them with building material. The dentine (dĕn'tĭn) formers line up on the inside, directly opposite the enamel workers. They get their materials from the blood vessels in the space which is later to be pushed inward to form the small "pulp cavity" of the tooth. The dentine battalion works inward from the outside till it reaches the pulp. Here it remains inactive till much later, when the tooth has already come through the gums. Then it may be called on to block the invasion of any enemy bacteria which have destroyed some of the dentine already built. The engineers then form more dentine to stop the onslaught of the bacteria.

Photo by Field Museum

It is the fashion in Angola, on the western coast of Africa, to chip and file one's teeth as this young man has done. But civilized peoples know that anything that makes even a tiny scratch in the enamel, endangers the life of the tooth. Never use a pin between the teeth, and never use gritty tooth paste or powder.

The enamel builders, on the other hand, work from the inside out; when they have once done their work, and the tooth has cut through the gums, they disappear. Thus, since the engineers are lost, the enamel can never be renewed when once it has been destroyed by the enemy. It must be kept clean to be kept whole.

What Teeth Are Made Of

When the tooth is fully formed, it has a "crown," a "neck," and "roots." It has a layer of enamel on the outside, thick layers of dentine underneath, very much like soft pumice stone, and a layer of cement covering the roots. But work on the teeth must still go on. They must be supplied with calcium (kăl'sĭ-ŭm) salts or lime, just as bone is, to make them hard and strong for chewing. And just as with bone, the special vitamins (vī'tȧ-mĭn) found in certain foods must be present so that the lime workers can deposit their burdens.

Even this is not the whole marvel of tooth building. After these twenty teeth have been used for four years or so, they all come out one after the other, during the next six years. They have worked hard and well at chewing, so well, indeed, that the jaws and mouth have developed in fine form. There are spaces between the first teeth to make plenty of room for the second, which are a little bigger. Thus the milk teeth, having done their work, fall in action, while chewing and chewing At least that is how it should be, for the first teeth must go early, and give the second teeth a chance to come up on time, straight and even.

If you examine one of these first teeth that has just come out, you will see that there is not very much to it. It seems to have no roots, and it is mostly hole! Instead of wasting all the good dentine, cement, and lime, the tooth engineers have undermined the roots of this first tooth and have used some of its materials to form the second tooth! The thing you hold in your hand is merely the shell of a tooth.

You know that some of the second teeth do not come in till we are almost grown. As we grow bigger, our jaws grow larger with the rest of us. They get longer in the back of the mouth, where there are no teeth at first. It is the big back teeth, the molars, that form last. Though they are second teeth, they do not take the place of any others, but crop up as soon as there is enough room for them in the jaw. The first of these, the six-year molars, cut through when we are six. The second molars come when we

are twelve, and the last when we are old enough to be wise. These are the troublesome "wisdom teeth." They are often annoying because the jaws have not worked hard and grown big enough to make room for them, so a wisdom tooth sometimes struggles and struggles, and aches and aches, trying to get through.

If you add these molars up, three on each side, both top and bottom, you will find that there are twelve; then add these to the twenty original teeth, and you will get thirty-two. And that is the number in the second set of teeth—or should be, if none have been pulled and if the "wisdom teeth" have struggled through all right.

As soon as the teeth come through the gums, they deserve care and attention, for they are the grinders in our food mill. The teeth should be brushed four times a day, before breakfast with clear water, and after meals with tooth paste or powder. They must be cleaned carefully, especially at bedtime, to rid them of the decayed food which is so attractive to the lurking bacteria that work hard and fast at night. Dr. Fones, who has done a great deal to keep the teeth of thousands of children healthy, says that there is a definite way to brush the teeth:

First, brush the outside surface of all the teeth. "Place the tooth brush inside the left cheek, and on the upper gums, and nearly close the teeth together. Make the brush go backward and downward, then slightly forward and upward, till it has traveled a complete circle." Use a light, rapid stroke and be sure to brush the gums as well as the teeth. "Never brush the teeth and gums crosswise." Clean the teeth on both sides of the mouth, as well as those in front, with the same circular motion.

Then "brush the roof of the mouth and the inside gums and surfaces of the teeth with a fast in-and-out stroke, reaching back on the gums as far as you can. Go back and forth across the roof of the mouth with this in-and-out stroke at least four times."

Brush the lower teeth and gums with this same in-and-out stroke.

Also brush all the chewing surfaces—the tops of the teeth—to remove all the food left there. Of course for the inside surfaces of the front teeth you will use a tooth brush small enough to reach them nicely.

The use of dental floss is very good for the teeth after they have been washed, because it cleans out all the food left between the teeth, where most decay takes place.

Besides brushing, another good thing for the teeth is to eat plenty of hard whole-wheat bread, raw vegetables, and fruits, especially oranges and tomatoes. These foods act as natural cleansers. They do not stick to the teeth, either, in the way soft, over-cooked foods and pastries do. Besides, they contain the vitamins that prevent illness as well as tooth decay. Whole-wheat bread is better than white bread, which easily sticks to the teeth; whole-wheat bread contains these vitamins, as well as lime salts. Fruit skins, and the outer coats of grains and vegetables also have a great deal of these substances so necessary for healthy teeth. There is an old saying that is very true, "Give your friend a whole peach; peel it for your enemy." Don't be your own enemy!

Photo by Prophylactic Brush Co.

Reading Unit No. 8

THE SCAFFOLD OF THE HUMAN BODY

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What our bones do for us, 2–318
How bones are held together, 2–318
How man became able to walk upright, 2–319
How bones grow, 2–320
What bones are made of, 2–320
Where blood corpuscles are born, 2–323
What the X ray has done for bone surgery, 2–324
How glands affect the growth of our bones, 2–324

Things to Think About

How can a muscle help us move?
What three big changes took place in the human skeleton before man was able to walk erect?
What substance hardens our bones?
Why is a broken bone harder to heal in an old man than in a young child?
How do doctors know just how badly and where a bone is broken?
What may cause us to become giants?

Picture Hunt

What part of your skeleton has its bones almost grown together in one piece? 2–319
What substance is found inside the bones? 2–320
What enables us to bend the knees or the fingers? 2–320
How do X rays help us to study the skeleton? 2–323
How do bones protect our soft parts? Color plate opposite 2–278

Leisure-time Activities

PROJECT NO. 1: To learn how soft bones can become when they have no lime, leave a long chicken bone in vinegar for forty-eight hours. What can you now do to the bone? 2–320

PROJECT NO. 2: Examine chicken bones for cartilage, and study the joints between bones.

Summary Statement

Bones keep us from collapsing into a soft, pulpy mass. Bones are hard, limey structures in which we find marrow. Red blood cells are made in the marrow of our long bones and then sent into the blood stream. Between most bones, at the joints, is softer material called cartilage. Muscles attached to different bones cause movement when they contract.

Photo by British Information Services

Every young person should drink at least a quart of milk each day, for milk is the body's best source of calcium, a mineral which is necessary for good bones and teeth. In addition, it helps our bodies to make use of other foods. These English school children are enjoying their eleven o'clock glass of milk.

The SCAFFOLD *of the* HUMAN BODY

Here We Are Going to Tell about the Many Bones That Hold Us Together, Keep Us Straight, and Help Us to Move Around

IF WE had nothing but a skin to hold in the various organs of the body we should be like squashy balloons filled with jelly. When we wanted to move we should only roll, bulging out in one place and squeezing in at another. Instead of that, the body is provided with a perfect motor machine—a machine that incases the vital organs, protects and supports them, and is fashioned to move beautifully, to run, jump, swim, climb, and dance gracefully and with freedom.

As you have already guessed, this machine is made up of the bones and muscles. The two work together to do our bidding: to go toward things we like and pick them up, to run away from those we dislike or fear, to sit, to wink, to eat.

The bones, some very tiny and some very long, are held together by strong bands of connective tissue called ligaments (lĭg'ȧ-mĕnt)—which merely means something that binds things together. These allow the bones to move at their joints. But the bones cannot move by themselves. It is the muscles attached to the bones across their joints which do the moving.

The muscles are made up of special kinds of cells which have the power of contraction. When they get a message, from a nerve of course, the cell fibers of the muscle contract—that is, they become short and thick, instead of long and thin. When a muscle contracts, it pulls up the bone to which it is attached, and there is movement.

The bones of man are arranged somewhat differently from those of any other animal. After thousands of years man has learned to stand upright, to work with his hands, to use his brain for thinking. He has learned to talk. These changes are all recorded in his skeleton, or bony system.

How these changes came about we are beginning to understand. In 1859 Charles Darwin and Alfred Russel Wallace told a shocked and surprised world how they thought the changes had come. At first people would not believe them or even try to understand what they meant. Now more and more people agree with their general theories and are trying to find out further and in more detail what happened to man to make him the greatest of all animals, not by his size or his physical strength, but by the power of his brain, which shows him how to rule the world in which he lives.

Three things happened to man's skeleton to make him stand upright. His backbone, instead of remaining as straight and stiff as that of a fish, or even of a dog, became curved in and out. Feel your own backbone and see. You will also feel some little bumps. These are the separate pieces of bone, called vertebrae (vûr'tê-brē), which fit into one another and make the backbone movable at every point. Because of its nice curve, the weight of the body is balanced evenly, with no strain, along the backbone. That was the first thing that happened.

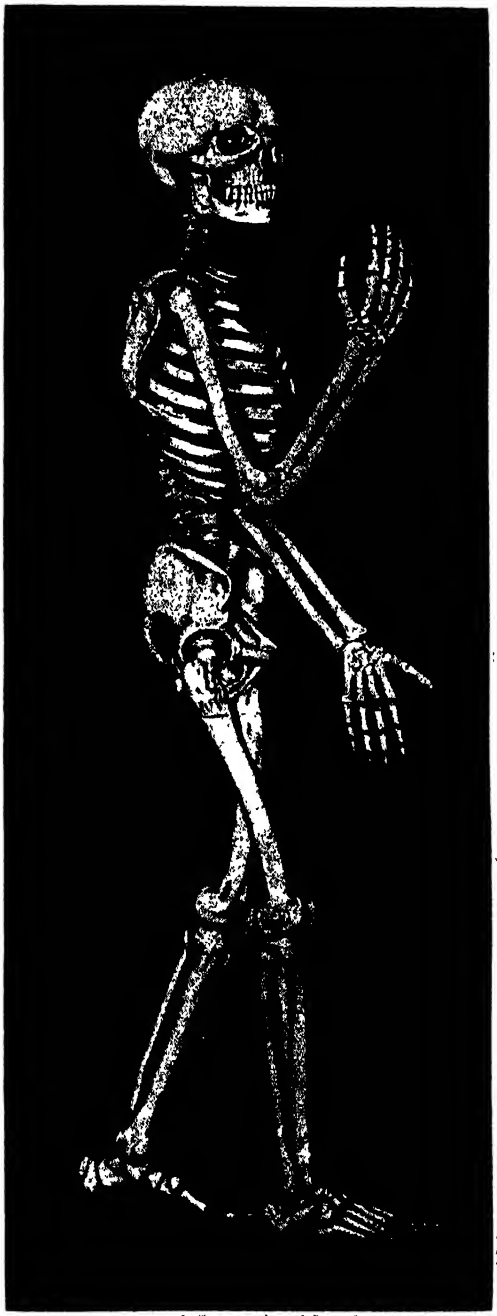


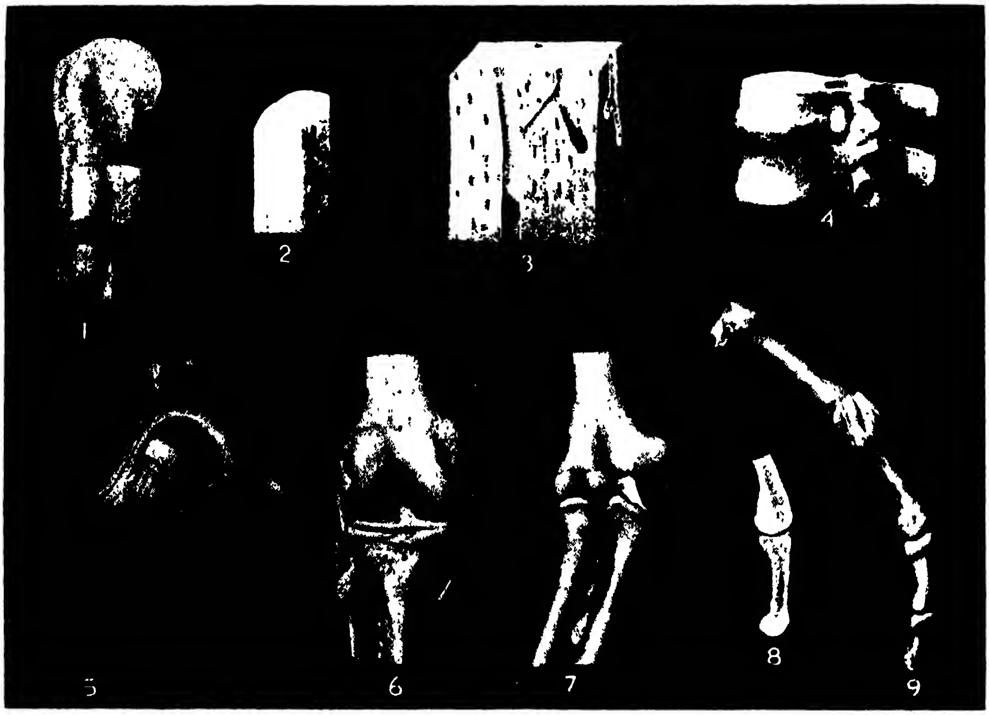
Photo by Clay-Adams Co., Inc.

The plan of your body's scaffolding and all its marvelous adjustments will be clearer to you if you study this complete human skeleton. You might try to find on it all the bones and joints mentioned in this story.

Then man's head shifted its position. It became attached to his backbone by the middle of its base. It was no longer top-heavy. Monkeys' heads are attached at the very back. That makes monkeys so top-heavy that they can stand and walk upright for only a little while.

Now, having got the weight of the body equally distributed and the head well balanced, a strong base had to be formed. So the feet were perfected. They protect the body from the jars and jolts of walking. They give it a bouncing quality, while still supporting it.

The bones of the feet are arranged in two arches. With the help of the leg muscles, these move readily and with ease. One of these arches runs backward and forward in the foot, from heel to toes; the other runs across the foot, just behind the toes. The two arches are strong springs, made out of bone. If we did not have these springs to step on, walking would be rather like riding a bicycle without tires.



Photos by Clay-Adams Co., Inc.

Here are some of the bones and joints seen more closely: 1. Bone at joint end, cut to show marrow within and the thin, skinlike periostium on the outside. 2, 3. Lengthwise section of bone, magnified. The grooves are opened canals for blood vessels and nerves; the dots are the living cells in their matrix of lime. 4. Two vertebrae, showing how they fit together. 5. Hip joint ball and socket. 6. Knee joint hinge. 7. Elbow joint hinge. 8. Toe joint hinge. 9. Bones and joints of a finger, clear to the wrist—all hinge joints.

The animals with four feet nearly always use all four for walking. A man never needs to use his hands for walking, so the hands are free to do other things. And the bones in his thumb have shifted their position so as to let him do far more with his hands. Instead of being in the same plane with the other fingers, the thumb is now "opposed" or opposite to them, and can close against them. In this position the thumb can touch even the little finger. And the hand can thus do many things: pick up objects daintily with the fingers instead of grasping them roughly with the whole hand; fashion delicate tools; sew fine clothing.

How Our Bones Grow

This development in the arrangement of the human body did not come about all at once. It took thousands and thousands of years.

The bones of a grown man are pretty hard, but a baby starts with very soft bones. For our bones grow in the same way as certain sponges. First the sponges are soft. They grow to their full size, and then they become hard. Calcium salts, another name for lime, are laid down in the cells of the sponge. This is just what happens to us, though our bones continue to grow even after they start to harden.

What Bones Are Made Of

Bones grow at their ends. That is how they get longer. They also grow in width. Otherwise people would be like bean stalks, long and spindling.

At first bones are made of a certain animal substance called cartilage (kär'tĭ-lāj), or gristle (grĭs'l). When you eat the leg of a chicken, a young "spring" chicken, you can see how much easier it is to bite into the

whitish, shiny stuff at the ends than into the harder middle part. That white part is the gristle or cartilage of which most of the bones are made at first, and of which joints are always made. Some of the cartilage in our bodies never turns into bone, but always remains gristle—as in the tips of our noses and the lobes of our ears. Gristle is tough and yet elastic. Feel your ears and nose, and see how tough and yet how movable they are. That is the nature of gristle wherever it is found.

No calcium salts can be laid down in the cartilage of bones, however, unless there is present in the body enough of a substance which we call vitamin D. Exactly how vitamin D helps the blood to lay down the salts we do not know. We know that direct sunlight shining on the skin increases the amount of vitamin D in the body. We have also learned that cod-liver oil contains a great deal of this same vitamin; and doctors have found that by feeding it to bow-legged children with rickets—a disease in which the bones remain soft—it is possible to harden the bones.

Photo by American Museum of Natural History

By studying this diagram you can see more easily just where each bone and joint goes and what its use is.

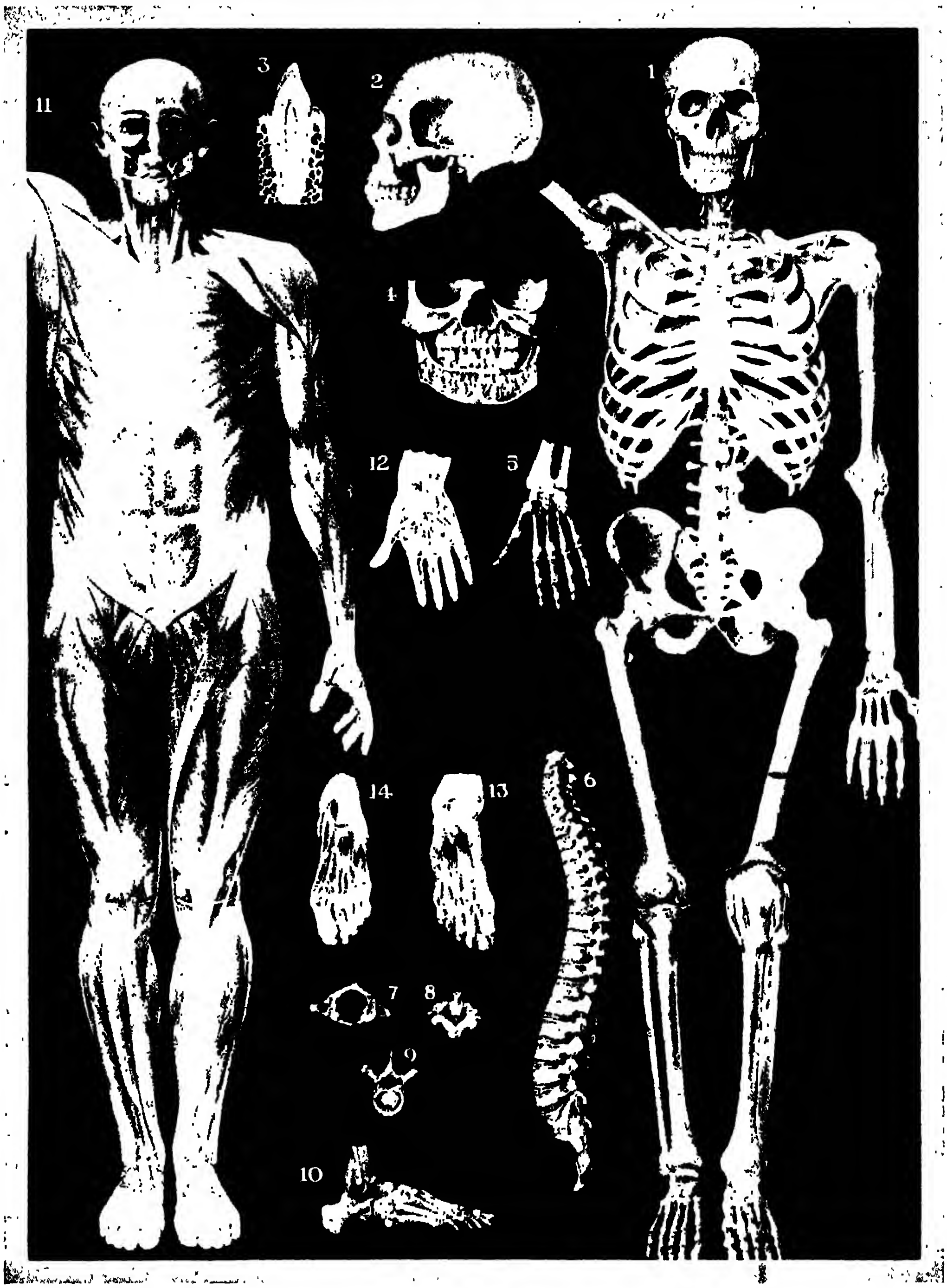
Children's bones are soft and pliant, while those of old people are hard and brittle, and thus easily broken. In children's bones there is much more animal matter, or gristle, present. In those of old people there is more mineral matter.

For this reason, too, children's bones are more easily mended when broken. When a child falls and "breaks" a bone, he usually has what is called a "green-stick fracture." That is like the injury given to a bough of a young tree by wind and weather. The bough is badly bent, but when spring comes it easily rights itself. A young bone, on account of the plaint and elastic cartilage, merely bends and cracks a little. It soon grows strong and straight again when set in place by a surgeon. Old bones, like old trees, snap and break. These fractures have a harder time mending, for the bones are broken all the way through and often they cut right through the flesh. Such a break is dangerous.

Bone building is even more complicated than we have said. Some day you may see, under the microscope, exactly how bones are formed: how little wandering cells eat their way stealthily into the gristle; how they make room for other wandering cells that carry the salts to be laid down; and how these cells change the soft gristle into hard bone.

There are about two hundred and six bones, big and little, in the body. It takes a long time to learn all their names and all the little bumps to which the muscles and ligaments are attached. Only doctors need to know them all. Our bony framework is made up of the head, the trunk, and the limbs. The trunk consists of the spinal column, with its many little vertebrae, the bones of the shoulder and the hips, and the ribs You know very well what the arms and legs are made of. Now study the diagrams of the skeleton to see what the different bones that give the shape to the body look like. If you want to learn all their names, so much the better for you!

As we have just said, the skeleton gives its shape to the body. The bones are so arranged that the left side is like the right. We have two arms, two legs, two cheek bones.



This page of pictures should clear up many points about both bones and muscles. 1. Front view of the human skeleton. 2. Side view of skull. 3. Section of tooth. 4. Lower part of skull of a five-year-old child. 5. Skeleton of the hand. 6. Spinal column. 7. The atlas, or first vertebra, from above. 8. The axis, which fits into it just below. 9. A larger, "thoracic" vertebra, from above. 10. Skeleton of the foot. 11. Muscles of the human body. 12. Muscles of hand. 13. Muscles of the foot, top view. 14. Muscles of sole of foot.

We are "bilaterally symmetrical"—that is, we are two-sided, and the two sides are just about alike.

If you cut a long bone, like one of the bones of the arm or leg, lengthwise or even crosswise, you will see that it is hollow inside. The hollow part is filled with the "marrow" you have seen when you have cracked the long bone of a chicken open. Marrow belongs to an entirely different system in the body. It is part of the blood system! In all the long bones, work is going on constantly. Thousands and thousands of little red cells, or blood corpuscles (kôr′pŭs-'l), are being turned out to find their way into the blood stream. They take the place of other blood corpuscles which have done their work and died.

Being hollow makes a long bone stronger than if the same amount of bony material were arranged in the form of a solid rod. You can see that for yourself: Take a sheet of paper, roll it into a hollow tube, hold it with the hand, and balance a book or a plate on top of the column formed. Had you ever thought that paper could be so strong as that? It would never hold up so much if it were rolled up tight into a solid little roll.

Being hollow also makes bones lighter. After all, they were made to be moved. It would be no easy matter to carry very heavy bones about with us. We should get dreadfully tired unless we had very strong muscles.

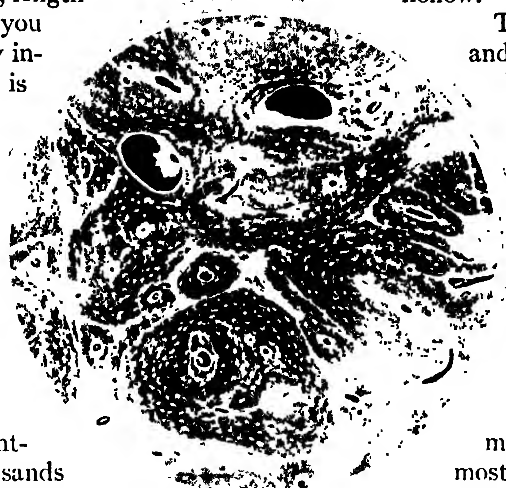


Photo by General Biological Supply House

A photograph of a section of human bone ground thin to show its structure, and placed under a microscope. The holes are nerve and blood canals; the dots are cells.

Photo by the National Museum

This X-ray photograph shows a man's foot in its shoe. Notice how the metal nails in the heel of the shoe stand out like stiff bristles on a scrubbing brush.

As it is, our bones combine the greatest lightness with the greatest strength possible. Construction engineers who build columns of stone or concrete make their columns hollow.

There are two hundred and thirty joints in the body, and they never creak! No engineer can ever hope to imitate their perfection. They are so cleverly and delicately formed that they allow for just the right amount of movement in exactly the right places. They are better geared and work more smoothly than the most delicate cogs in the smoothest machine.

There are many reasons for this. A joint is a place where two bones meet. Bones at their joints are made of cartilage, or gristle. This tough and elastic tissue forms a smooth cushion or pad between the two bones. That lessens the rubbing, or friction, between them. And to do away with the rubbing altogether, there is a lubricating fluid which keeps the joint well oiled and working smoothly. Very little is ever wasted in this body of ours; and the cells of the cartilage, when they wear out and die, are turned into the lubricating fluid that oils the joints.

To keep the ends of the bones in place, so that they will not be dislocated at every move, the joints are well wrapped in strong bands of connective tissue, the ligaments. These hold the bones firmly together, and yet allow for plenty of movement.

Some joints have a freer movement than others. In fact, the movement of joints varies from none at all at the jointures of the bones of the skull to the great circular movement of the arm at the shoulder.

The "Little Fountain"

Different kinds of joints make this variety of movement possible. The bones of the skull tightly interlock with one another. No movement is needed. The skull houses and protects our most precious organ, the brain. It would be a terrible and dangerous thing if the joints of the skull were movable. Only in little babies, where the covering at the top of the head has not yet hardened into bone, is any movement possible. The Italians named this soft spot "the little fountain" because it beats up and down. It is so delicate that a mother will never let anyone touch her baby's head.

Another kind of joint in the body is the hinge joint, which works like the hinge of a door, in one direction only. The fingers have hinge joints. So have the elbow and the knee. The lower jaw has a kind of hinge joint which also allows movement from side to side for chewing.

The shoulder and hip joints are "ball and socket" joints. A knob at the end of the upper arm fits into a shallow cup at the shoulder. So the arm can revolve around and around, without stopping. The socket at the hip is deeper. It is stronger, too, but it does not allow for so much movement as the one at the shoulder.

The Ancient Art of Mending Bones

The joint between the head and the neck is a "pivot" joint. The head can turn from side to side, or nod up and down on account of its wonderful pivot.

Injury is the great danger of bones. This is because they are brittle. Thousands of years ago, way back in the time of the Egyptians, the medicine men knew nearly as much about setting broken bones as doctors did fifty years ago. Mummies have been found showing that their bones had been broken, and mended in splints, just as they are mended this very day!

Until fairly recent times a bone surgeon worked very much in the dark. But with the discovery of the X ray, the task of the surgeon became an easier one. With its help, he can see exactly what he is doing.

After a broken bone is set, it is put into splints or a plaster cast to heal. Healing, in the bone, is the same as growth. New bone-forming cells make a bridge across the broken part. Other bone cells come in to fill the gap. You can always tell where a bone has been broken, because the new bone cells do their job very thoroughly. At the point where the bone has been broken they even add a little extra bone. That makes a tiny bump, and the bone is stronger than ever at that point. What starts the new bone cells working, and what stops them when their work is done, no one knows.

Why Some Are Tall and Others Short

Now we have said a good deal, in a general way, about the bones and joints. But we have not yet told why some people are as tall as giants, and others as short as dwarfs or midgets, while most of us are just average in size.

There are several special glands that regulate the growth of our bones. One is at the base of the brain, and another is right in front of the Adam's apple. These send their products out into the blood, just as the bone marrow also does. The products that circulate in the blood stream are called "hormones" (hôr′mōn). This name comes from a Greek word meaning "to excite." Hormones excite other cells to action. These special hormones excite the bone cells to growth.

When the gland at the base of the brain, which is called the "pituitary" (pĭ-tū′ĭ-tā-rĭ) gland, works too hard and manufactures too much of its hormone, the person becomes a giant, with big head, big hands, and big feet. He is like the giant in the circus, or the ogre in "Jack and the Bean Stalk." When the gland in front of the Adam's apple, the "thyroid" (thī′roid), is sleepy and does not work properly, a misshapen dwarf is formed When both glands fail to work, a midget is formed. He is little, but perfect in form.

Reading Unit No. 9

HOW A MUSCLE DOES ITS WORK

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

The three kinds of muscles that work for us, 2–326
How muscles "know" what to do, 2–326-27
What muscles look like, 2–327
What tendons do, 2–327-29
How we move our bones, 2–329
How the brain controls muscles, 2–329-30
What goes on in a muscle, 2–331
Why we get tired, 2–331

Things to Think About

What kind of muscles help us to run and work?
What kind of muscles work automatically, even when we sleep?
What special ability do muscle cells have?
How can a muscle move bones?
How is a muscle connected with the brain?
Why are muscles red in color?
Why does exercise or work make us feel very warm?
What accumulates in a muscle if we do not rest it?

Picture Hunt

Where are the deltoid, trapezius, biceps, and triceps muscles? 2–328
What muscle takes care of our breathing day and night? 2–329
Where is the diaphragm located? 2–329
What happens to muscles that are used a good deal? 2–330
What are flexors and extensors? 2–331

Related Material

How do we know, without looking, what our body is doing? 2–285
How was it learned that different parts of the brain control different muscles? 2–388
What exercises shall one undertake to make the body strong and healthy? 2–415-16

Summary Statement

We have three kinds of muscles. Voluntary muscles are controlled by the brain. Involuntary muscles work day and night without our knowing it. Our diaphragm, stomach, and intestines have such muscles. The heart has a special kind, the cardiac muscles, that work automatically, too. When a muscle contracts, it gets shorter and therefore pulls on a bone, thus helping us to move about.

All together now—heave ho! Stretch every muscle! And though the boys have no time to think about it, in every arm and leg a whole troop of muscle fibers is pulling all together, just as the lads themselves are doing.

Photo by H Armstrong Roberts

HOW *a* MUSCLE DOES ITS WORK

This Will Tell You Why Your Heart Keeps Beating, and What Happens When You Crook Your Finger or Run a Race

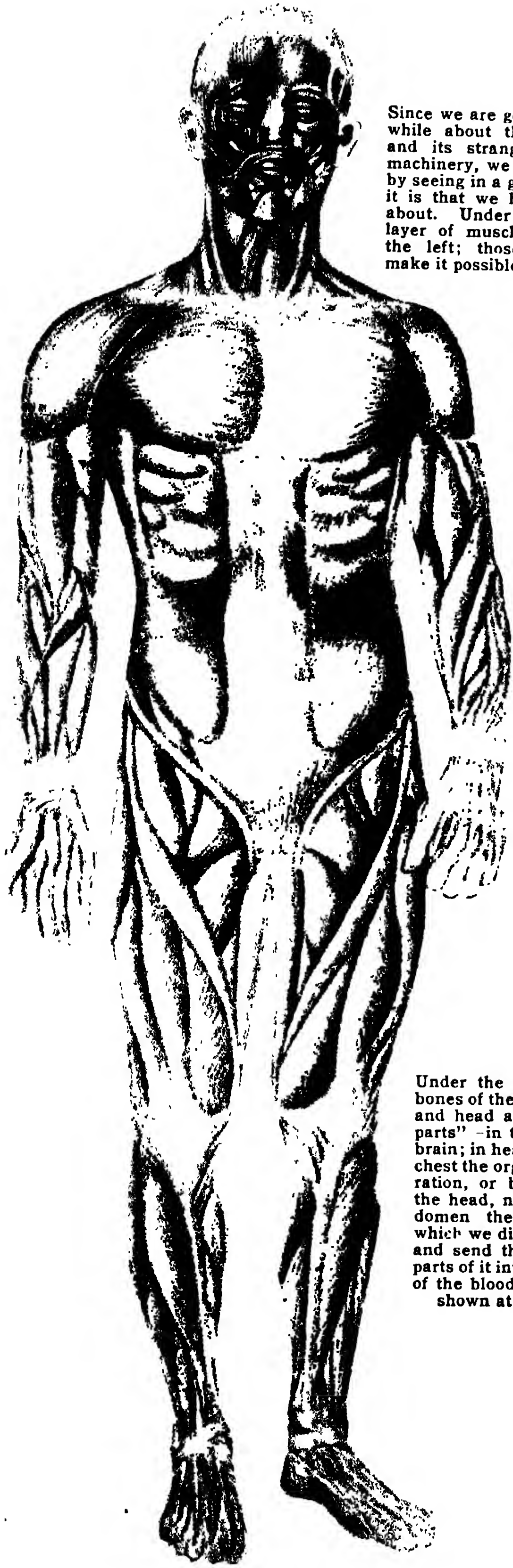
WHEN we want to move, all that we do is to tell a muscle to pull on a bone and move it. We nearly always do it without thinking. We do not really know that we have told the muscle to pull the bone; but that is what happens, all the same.

Now the muscles that pull at our bones are only one of three kinds of muscles in our bodies. They are the muscles that move us when we will it; and we call them "voluntary" muscles, from a Latin word meaning "will." When we want to walk across a room, or climb a tree, or write, or sew, the "higher part" of our brain sends out messages through our nerves to all the muscles we are going to use. Then the muscles move, and we run and climb and play and work.

But there are other kinds of muscles in the body that work for us twenty-four hours a day without ever having to be told to do it. We should never be able to sleep if we had to tell them what to do and when to do it. The heart is made of muscle of this kind; it pumps blood all over the body, and never stops working from the minute it first starts going. When it does, we die. The heart muscle is a very special kind of muscle. There is no other like it in the body.

The third kind of muscle, like the heart, works day and night. It forms the walls of the blood vessels, and of the stomach and the intestines. The tiny muscles that make our hair stand on end, or give us goose flesh, are of this type also.

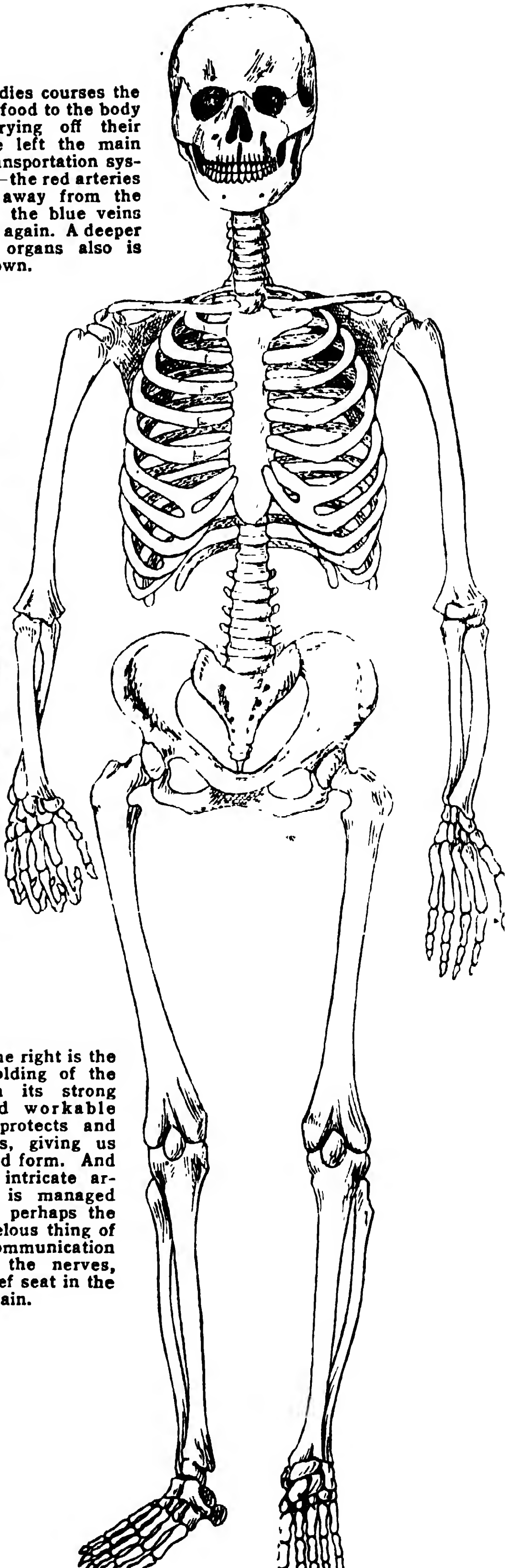
The heart and visceral (vĭs′ēr-ăl) muscles —the stomach and intestines are called the "viscera" (vĭs′ēr-ȧ)—work automatically. To be sure, they have nerves and receive messages. But it is a "lower part" of the brain that takes care of them, a part of the brain that knows nothing about thinking. It is just as if something had turned on a switch when we were born, like the switch



Since we are going to talk for a while about the human body and its strange and cunning machinery, we had better start by seeing in a general way what it is that we have to find out about. Under our skins is layer of muscle, as shown at the left; those strong fibers make it possible for us to move.

Under the muscles and bones of the body's trunk and head are our "vital parts" –in the head, the brain; in head, neck, and chest the organs of respiration, or breathing; in the head, neck, and abdomen the organs by which we digest our food and send the life-giving parts of it into the stream of the blood. These are shown at the right.

All over our bodies courses the blood, bringing food to the body cells and carrying off their waste. At the left the main lines of this transportation system are shown—the red arteries leading blood away from the pumping heart, the blue veins bringing it back again. A deeper layer of vital organs also is shown.



Lastly, at the right is the bony scaffolding of the body, with its strong bones and workable joints; it protects and supports us, giving us strength and form. And the whole intricate arrangement is managed by what is perhaps the most marvelous thing of all—the communication system of the nerves, with its chief seat in the brain.

of an automatic electric iron that keeps on sending a current till the iron is hot enough, and then stops when the iron gets too hot. The "lower part" of the brain seems to know just how much current to send to these muscles, though we never know or feel what it is doing. So these muscles are called "involuntary" because they keep on working without our willing it. They are most important muscles, for they take care of our "inside arrangements."

There is another great difference between different muscles. The fibers of the voluntary muscles have dark and light bands or stripes running through them. We do not yet know what makes these stripes, though the scientists are working patiently to find out. We do know, however, that the muscles having these stripes work faster than the others.

In the involuntary muscles, all except the heart, there are none of these dark and light bands. The muscles that have these bands are called "striped" or "striated" (strī′āt-ĕd) muscles; the others are called "unstriped" or "unstriated." The heart is in a class all by itself. It is an involuntary muscle, and yet it is striped.

All three kinds of muscle—from the great triangular sheet, stretched flat across the back, through the middle-sized muscle that lifts one of our eyebrows, down to the tiny muscles in the skin that give us goose flesh—all three kinds are made of fibers. The fibers are giant cells, though of course the cells are still so tiny that they can be seen only through a microscope. In these cells lies the peculiar power of contraction which makes them muscle cells.

Photo by Clay-Adams Co., Inc.

This picture gives a general idea of the muscles of the human body as seen from the front and one side. Notice the great flat bands of muscle fiber across the chest and up and down the arms and legs.

When a boy pulls up his forearm as hard as he can and says, "Look at my muscle," he has contracted the muscle as much as possible. That is what pulls up the forearm, and it is what makes his muscle gather in a big knot and turn hard. When he lets it go again, it gets longer and softer.

Now this muscle, like the others, has two ends and a middle. It is the middle that the boy is "showing off." This part, called the belly of the muscle, is the red meat that we all know; for when we eat beef, we are eating mostly muscle. The meat is packed tight with many muscle fibers or cells, each in a little bag that tapers to a string at the ends. These many, many fibers making up the muscle lie in another, larger bag that forms the muscle bundle.

If you have any trouble finding the ends of a muscle, you might feel for a tough cord that is the end of the muscle in your upper arm—the "biceps" muscle that so many people like to show. Move your arm up and down and feel along it just above the

A. The great triangular muscle is called the trapezius; the one that caps the shoulder, the deltoid.

B. Under the outer layer of the "shoulder girdle" is a deeper layer of muscle, which is shown in this picture.

Photos by Clay-Adams Co., Inc

C. Here the joint at the shoulder is outlined twice, to show the movement of the shoulder blade.

D. The extensor of the upper arm at the left above is the triceps; the flexor - right--is the biceps.

elbow, a little to the inside, till you come to something that reminds you of a little rope. Notice what a strong, tough band it is. That is one end of the muscle, and it has to be strong to keep from tearing when you pull with all your might.

This rope of connective tissue is called a "muscle tendon." The easiest one to find is in the back of your heel. It belongs to the calf muscle. It is even tougher than the one at the elbow, for it is the tendon that helps you to step from heel to toe. It is called

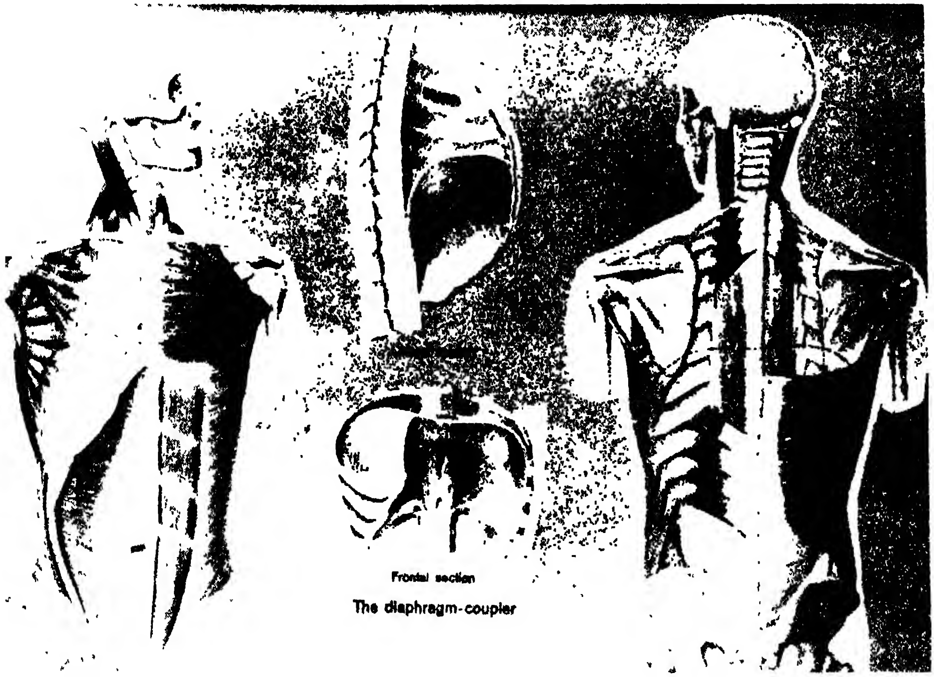


Photo by Clay-Adams Co, Inc

One of the most important muscles we have is the diaphragm, a strong muscular wall separating the chest cavity from the abdomen; it is the diaphragm which moves downward to make room for air in the lungs when we breathe in. The diaphragm is attached to the ribs on the side and to the spinal column at the back, as can be seen from the two smaller pictures in the middle above. Its position in the body is shown in the two larger pictures by the dotted line. These larger pictures show also others of the muscles of the trunk; in each, the side to the left of the page has been cut away to show a deeper layer of the muscle fibers.

the "tendon of Achilles" (ȧ-kĭl'ēz), because, as you may remember, the only place where Achilles could be wounded was in the heel.

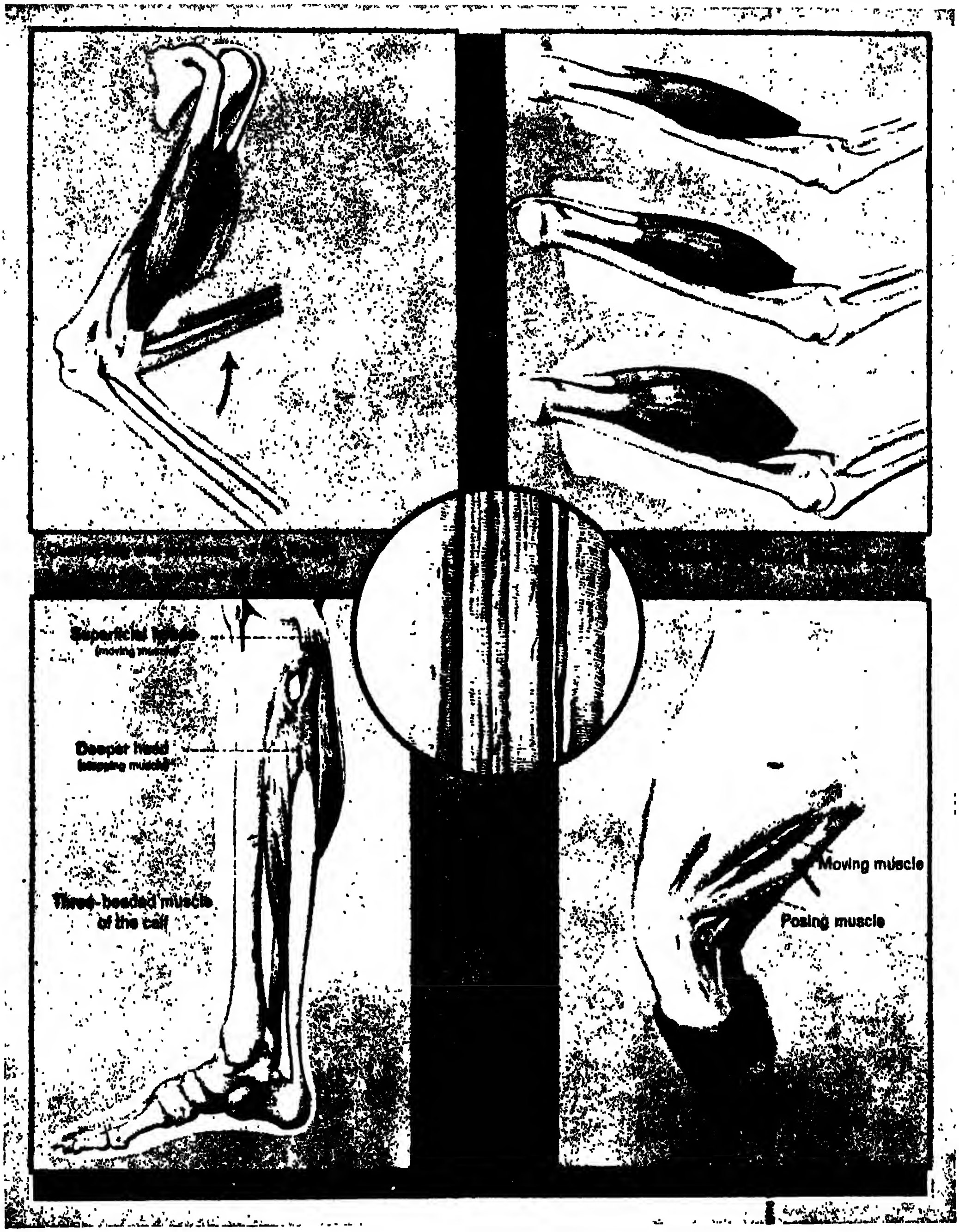
A muscle is attached to a bone at each end by its tendon, and is free or loose in the middle. This allows the fibers in the middle to contract—each fiber becoming short and thick instead of long and thin—and to pull on the bones through the tendons.

How We Move Our Bones

In order to move a bone, a muscle must be attached to it across a joint. Then, when the brain sends messages to the muscle to go to work, the little fibers contract, pull at their tendon, and draw the bone toward them. So a muscle is a little like a great band of tiny sailors pulling at a rope. The master says, "Heave ho!" and each fiber heaves. All of them together move the bone

We have said that the muscle which pulls up the arm is called the biceps (bī'sĕps). "Bi" means "two," and this muscle is divided in two at the upper end, where it is attached to the shoulder blade. Now if there were no other muscle to pull at the forearm, it might just stay up forever, once the biceps has pulled it up. But there is another muscle called the "triceps"—because one end is divided in three—which works along with the biceps. The triceps lies along the back of the upper arm, and its tendon is attached to the lower arm over the back of the elbow joint. When we want the forearm down again, all the little fibers of the triceps contract and pull the arm toward them, to straighten it out again. Many of our muscles work in pairs like this. The muscle that raises the bone is called a "flexor" muscle. The one that extends it again is called an "extensor."

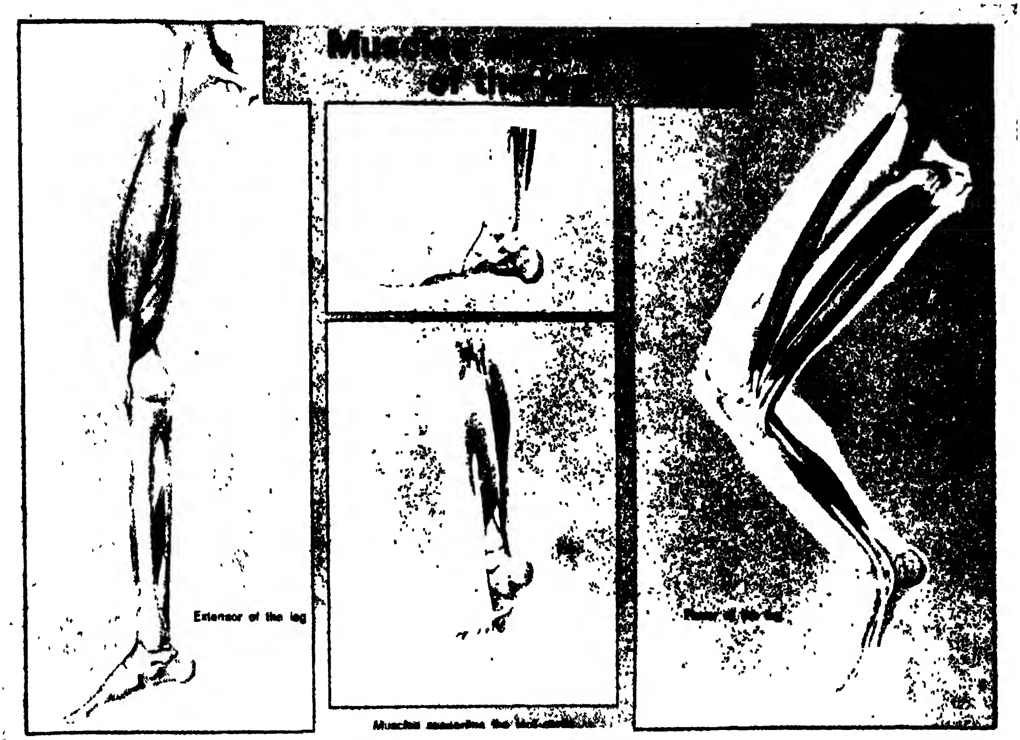
Every muscle fiber is a complete power house with its own road traffic and telegraph lines. The brain, as we have said, is the



Photos by Clay-Adams Co., Inc

Here is a group of pictures showing something of how the muscles of arms and legs work. Notice particularly the picture in the circle, center, which shows an enlargement of the fiber of voluntary muscles.

master of the muscles. So every muscle fiber has its own telegraph station in which a tiny nerve fiber from the brain ends. Through a special wire called a "motor nerve," the brain sends messages to the muscle fiber to work. Now in order to have energy or power for its work, the muscle must get its supplies just like any real power



Photos by Clay-Adams Co., Inc.

We can see clearly from these pictures how the extensor extends the leg and the flexor flexes, or bends, it. Note also the heel muscles, which you can feel for yourself easily enough through your own flesh.

house. It gets its loads of food materials and oxygen from the blood, which carries on a traffic all over the body. The muscle fiber stores these supplies. Then it is ready, when the message comes, to start its machinery.

How Our Muscle Engine Works

A muscle fiber is not a heat engine, like the steam engine, as scientists once thought. It is a "chemo-dynamic" engine. This means that it is a machine in which chemicals work together to form chemical energy or power which is changed into work without passing into the form of heat.

Now let us say a word about what goes on in the muscle fiber when the machine is working. First, there is the message sent from the brain through the nerve as a real electrochemical current. This current sets the machine working, and two changes take place almost at once. No scientist as yet can tell which takes place first. An electric current is generated by the muscle fiber, passes through the cell, and disappears almost immediately. The other change is chemical, and it is more important. In some unknown way this chemical change, in which the food stored in the muscle is used up, causes the muscle fiber to contract and to do its work.

A muscle's efficiency is rated high, for 28% of the energy set free is turned into work. The heat comes only as a by-product. It is not wasted, since we are warm-blooded animals, but is used to keep the body warm.

When a muscle works for a long time, it forms certain substances—lactic acid and carbon dioxide (dī-ŏk'sīd)—which are harmful. The blood cannot take them away quickly enough. They act on the nerves, and give us the tired feeling we all know when we have worked our muscles hard. This tired feeling is a warning. It means, "Stop till you are in trim again."

Reading Unit No. 10

WHAT GOES ON IN YOUR LUNGS?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

What Lavoisier discovered about breathing, 2-333-34
What oxidation is and where it takes place, 2-334
How plants and animals get oxygen, 2-334
How the lungs are fitted for getting air, 2-334-36
How oxygen reaches all corners of the body, 2-336
What happens when we breathe, 2-337-38
How the blood gets oxygen and carbon dioxide, 2-338-39
What makes us breathe faster during exercise, 2-340

Things to Think About

Why does the diaphragm move downward in breathing?
Where in the lungs can blood pick up oxygen?
Why must we exhale?
What controls our breathing during sleep?
What causes you to breathe faster when running?

Picture Hunt

What organ is closely connected with the lungs? Color plate after 2-326; also 2-335
Why does the windpipe divide into many branches? 2-334
What separates the chest cavity from the abdominal cavity? 2-335
Why are air sacs thin-walled? 2-336-37

Leisure-time Activities

PROJECT NO. 1: To learn what capillaries are, examine a live fish's tail under the microscope, 2-334.

PROJECT NO. 2: Make a large wall chart showing the lungs, trachea, and its branches, 2-334.

PROJECT NO. 3: Learn how to revive a person who has been too long under water.

PROJECT NO. 4: Determine the average rate at which a person breathes, 2-340.

Summary Statement

Breathing furnishes our cells with oxygen for energy and also enables us to get rid of poisonous carbon dioxide and some water. Our lungs are spongy and contain about a billion air sacs which give oxygen to the blood capillaries surrounding them and relieve the blood of carbon dioxide.

Ready—set—go! And off they will dash, boy and dog, breathing fast and deep and using up oxygen at a great rate. When they get to the goal, the little dog's tongue will be lolling out of the side of his mouth, and the boy will be panting and opening mouth and nostrils as wide as he can to help send oxygen and more oxygen to the body he has been working so hard in his race.

Photo by H. Armstrong Roberts

WHAT GOES *on in* YOUR LUNGS?

Awake or Asleep, and Whether or Not You Are Thinking about It, You Are Always Running a Chemical Plant in Your Chest without Which You Would Be Poisoned in a Few Minutes

LET us imagine the great Lavoisier (lȧ′vwȧ′zyȧ′) as he paces excitedly up and down the floor of his laboratory. He is deep in thought. Suddenly he begins to talk to himself. "Carbon dioxide and oxygen. That's it!"

Again he is silent.

He stops before the open door, and calls, "Come, Sequin, I've hit on it at last. I've got the right idea."

And hardly has his laboratory assistant had time to enter the room before Lavoisier continues, "The Greeks were wrong when they thought that the lungs regulated the heat of the body, but they were right when they said that the lungs take in a substance—'pneuma' (nū′mȧ) they called it—that is necessary to life.

"Pneuma is this oxygen that we find in the air! And old Galen (gā′lĕn) was right, too, when he said that it is the work of the lungs to take in this pneuma—'vital spirits,' he called it this time—and to give off a 'sooty vapor.' He was nearer the truth than the man who now says that the blood gets red because it's shaken!"

Sequin tries to put in a word, "And where does this——"

But Lavoisier interrupts him, "I understand it at last! The lungs take in oxygen (ŏk′sĭ-jĕn)—the 'vital spirits' of Galen—and give off carbon dioxide (dī-ŏk′sīd)—his

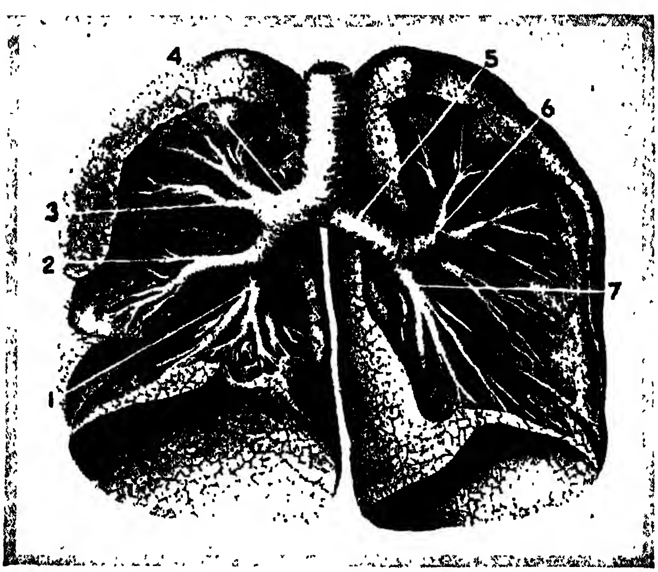
'sooty vapor'—because oxidation, or combustion, takes place in the lungs!

"Come, Sequin, we've wasted too much time already. Let's get to work!"

It is more than 150 years since the great French chemist set out to prove his theory that combustion, or "oxidation" (ŏk′sĭ-dā′shŭn), takes place inside the body as well as in external nature. He was such an able investigator that in the years since then the scientists have disproved only one point of his theory. Oxidation, the process necessary to life, does go on inside us, but in the tissues of the body, and not in the lungs.

And what is oxidation?

It is the chemical combination of oxygen with some other substance. Whenever anything burns, oxidation takes place, and energy is given off in the form of heat. When a piece of wood burns, the oxygen combines with the carbon of the wood to form carbon dioxide, a gas, and water vapor, or steam. When sugar burns, it also forms carbon dioxide and water.



This picture shows the lungs in front, with part of their substance cut away to expose the branching air passages. The main stem at the top is the end of the trachea, or windpipe, by which air enters the lungs. It branches into the two bronchi, or bronchial tubes, one for each lung. The right bronchus (4) has three main branches (1, 2, 3), and the left bronchus (5) has two (6, 7).

How Food Gives Us Energy

Now materials from the food we eat go to all the tissues of the body, and in the cells of those tissues the materials are "burned up" to give us the energy we need. We need it for heat, for movements, for growth. That burning up of the materials is oxidation. It is going on in us all the time.

In order that it may go on we must take oxygen into our systems. And in order that the carbon dioxide that results from oxidation may not poison us, we must have a way to get it out of our systems. Those are the reasons why we have to breathe.

All living things must breathe to keep alive. The tiniest blob of living matter, the one-celled animal, "breathes." It takes its oxygen in directly through its whole surface. Plants breathe through special openings in the under side of their leaves. Grasshoppers have a number of little "windows" over their bodies to receive air. This arrangement gives the grasshopper all the oxygen he needs, but it would not do at all for a dog or an elephant. It would not do even for the fish. A fish is a cold-blooded animal, and does not need to oxidize in order to keep warm; but it does need to do so for moving and for growing. So all the higher animals have a special way of getting oxygen. The fish have gills for getting oxygen out of the water. Man and other warm-blooded animals have lungs to get it out of the air.

The lungs are really millions and millions of air sacs surrounded by thousands and thousands of tiny blood vessels, the capillaries (kăp′ĭ-lâ-rĭ). The arrangement of the air sacs makes the lungs spongy, and gives them a very great surface area. If every bit of the lung surface in a pair of lungs were spread out, it could line the ceiling, walls, and floor of an average living room, and still have some left over. The little air sacs can very easily catch and hold a large amount of air. A hundred times more air reaches the lungs than touches the skin at the same moment, for the lung surface is more than a hundred times greater than the whole area of the skin!

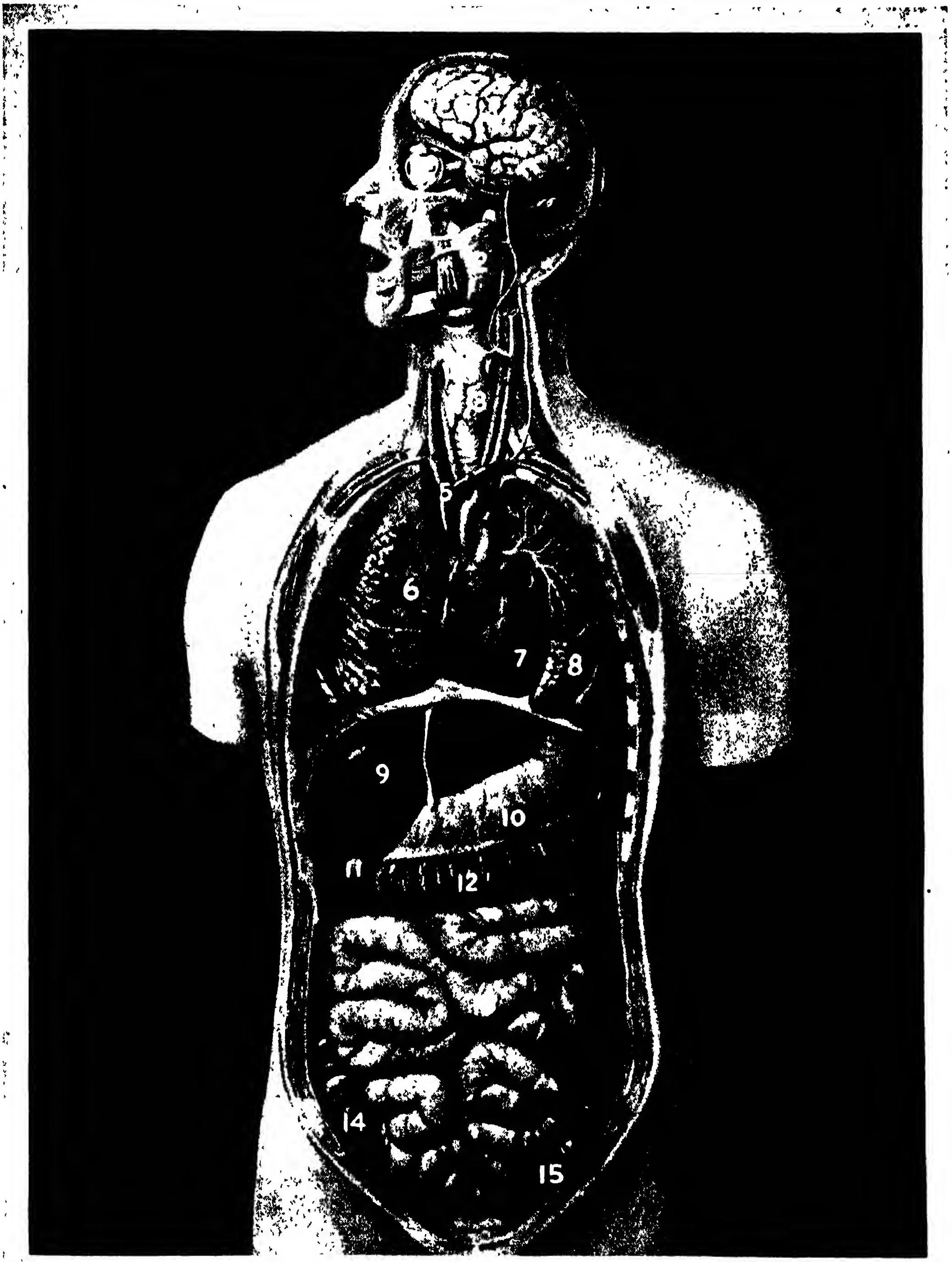


Photo by Clay-Adams Co., Inc.

It would be a good idea, before we go any further with this story of our bodies, to get clearly in mind the general arrangement of the parts of the machinery within us. In this diagram the most important of the organs we use in breathing and digesting our food are shown in position. 1. Brain. 2. Parotid gland, which makes saliva. 3. Thyroid gland, which is concerned in body growth. 4. Trachea. 5. Jugular vein. 6. Right lung. 7. Heart. 8. Left lung. 9. Liver. 10. Stomach. 11. Gall bladder. 12, 14, 15. Colon, or large intestine. 13. Small intestine. The arch of the diaphragm also shows just below the lungs and heart.

The walls of the air sacs are thinner than the finest tissue paper. The walls of the capillaries are just as thin. Now the blood has been taking up the carbon dioxide from the tissues all over the body, and has brought it through the veins to the capillaries around the lungs. There it must be transferred to the air in the lungs, to be breathed out from the nose. At the same time the blood must take in the oxygen that has been breathed into the lungs with the air, and carry it through the arteries to all the tissues. And it is very easy for the blood to do all this through the thin walls of the air sacs and capillaries. The process goes on all the time, and we need never think about it; but if it stopped for a few minutes we should die. We must have oxygen to keep alive. Thus the lungs work with the entire blood system. And now we know why we sometimes speak of the "breath of life."

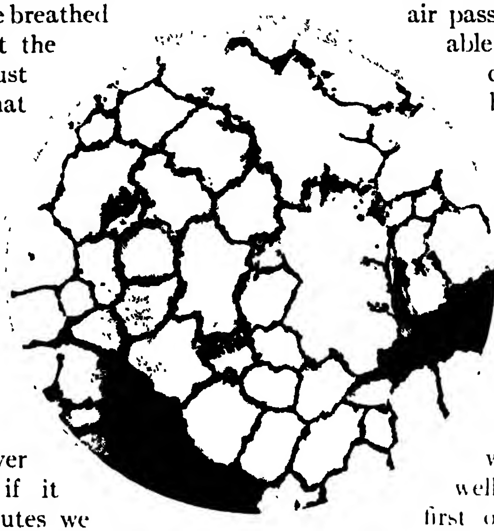


Photo by General Biological Supply House

This is a section of a human lung seen through the microscope. The little sacs are called air cells, or alveoli. There are about 400,000,000 of them in each lung.

There are really two steps in breathing: the breathing of air by the lungs, called external breathing, or respiration; and the breathing of the oxygen by the cells, or internal respiration.

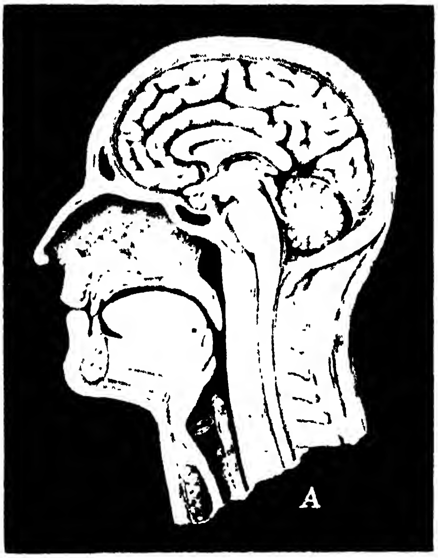
We all know that when we breathe, the chest rises and the abdomen bulges. But do you know what is going on underneath?

How the Air Gets through Our Bodies

The air passages leading to the lungs from the nose and mouth are never closed. They have special C-shaped hoops of cartilage or gristle to keep them open. Feel your throat and see. Thus there is always an open space through which the air can flow—even through the voice box, which is at the top of your windpipe where your Adam's apple is. Now, the main tube that you can feel in your throat keeps dividing, as it goes on down, just like a tree with two main branches which keep forming smaller and smaller branches that end in many little twigs. The last and tiniest air passages of the lungs lead into small air spaces whose outer walls are formed into the even smaller air sacs. Between every two such air sacs lie the little blood capillaries.

But the tubes to the lungs are not simply air passages. They are remarkable cleaning and filtering machines which protect the body from its millions of enemies in the air. The particles of dust in the air are tiny airplanes on which the germs of the most dangerous diseases travel over the world. If it were not for the defenses in our air passages, to stop such germs, most of us would be oftener sick than well. First of all, at the very first outpost, the nose stands sentinel. With its little hairs it snares the dangerous particles of dust and captures their murderous riders. Yet many enemies slip through the first barricade. They are likely to be caught a little further on by two kinds of defense mechanisms. The linings of the nose and other passages are studded with millions of rows of active soldiers, the little hair cells. These also catch the dust, as the hairs of the nose do, and then by a concerted action, more perfect than that of the best-trained football team, they pass it back upward into the nose by a simple oarlike movement. The other line of defense is also effective. The lining manufactures a gummy substance, as well as a watery liquid, in which the dust and its dangerous burden stick. Drowned in this sticky mucus, they are also passed upward into the nose. Later they are thrown out when we blow our noses, or sneeze, or cough.

And if these three means of defense still have allowed the unseen enemy to pass through, the lungs themselves take up the battle. For they contain many little wan-



Photos by Clay-Adams Co., Inc

This is a cross section of the head, showing the relationship between nose and mouth, and between windpipe and gullet. The air entering the nose when we breathe goes first into the pharynx, which shows as a dark spot at the back of the nasal cavity; then into the larynx, which opens sharply outward at the base of the tongue; thence down the trachea to the lungs.

This is a group of air cells of a human lung, greatly enlarged. The tiny blood vessels hug the walls of the little sacs, intertwining about them like an infinitely delicate net. And each gives off its load of carbon dioxide through the thin walls of the sacs and takes in its place a load of oxygen to carry back to the billions of living cells in the body. Without this oxygen we should quickly die.

dering cells that destroy the germs by surrounding and eating them.

The only sort of ordinary dust that easily escapes our protectors is soot and coal dust That is why if you examine a miner's lungs, you will always find them pitch-black. A city man's are grayish, from the city smoke, while a newborn baby's are a bright pink.

Are You a "Mouth Breather"?

The air passages must do one more thing before the air is exactly right for use by the lungs. They must moisten and warm it. The nose, especially, is active in this work. It is full of many tiny blood vessels that bring their hot blood to the nose. Here the blood gives up some of its heat as well as some of its moisture to the air. The watery substance manufactured by the lining also moistens the air. So does the blood in the other passages; but the nose is a very important passage in this respect, and that is one reason why we should breathe through the nose. "Mouth breathers" can often be told by the little dry cough they have. The cold, dry, dust-filled air is irritating down below, and the tissues try to get rid of it by coughing it out.

Now what makes the air rush into the lungs? Can you remember when you used to think you pulled it in with the end of your nose? Do you know now exactly how it is pulled in?

The ribs make a sort of crate around the lungs and the heart. In fact, we call this crate a "chest." The floor of the crate is a very powerful dome-shaped muscle called the diaphragm (dī'ȧ-frăm). It has a strong tendon which is attached downward from its center. And it is with muscles—the little muscles that join the ribs one to another, and the big strong diaphragm muscle—that our story begins. The muscles as you know, are the moving machines of the body. When they get the message from a nerve they contract. The rib muscles pull the ribs upward. The tendon pulls the diaphragm downward, making it flat instead of dome-shaped. It presses on the organs in the abdomen so that they bulge outward. The action of these

muscles makes the chest box larger from top to bottom.

Breathe in deeply, at the same time holding your ribs at the sides. What else happens? Don't the ribs themselves bulge? They are like hoops that are arranged, not in a line parallel to the floor, but slanting a little downward toward it. Now make believe the fingers of your hand are ribs. Hold them sidewise with your little finger nearest the floor, and point it downwards. Then suppose that a muscle pulls them upward at the finger tips. Do you see how that bulges the fingers out? That is how the ribs bulge out when they are pulled upward, and make the chest cavity larger from front to back.

What Happens When We Breathe?

The lungs—incased in their special bag, with its special fluid that prevents friction when they move—are elastic like a rubber balloon. So what happens when we breathe in is fairly simple. The muscles make the chest larger, and air, full of oxygen, rushes in to fill the empty spaces in the lungs. Then the muscles relax again and go back to their first position. The chest becomes smaller from top to bottom, and from front to back. The lungs, being elastic, get smaller too, and so push the air, now warm and moist, out into the world again. It is now laden with carbon dioxide, which we are throwing off.

Tight clothing changes the story. It presses on the abdomen and hinders it from bulging. The diaphragm muscle cannot press downward enough, and the lower part of the chest cannot expand sufficiently. People who wear tight clothing expand only the upper part of their lungs, so that very little air reaches the lower part. Since the lungs are widest at the bottom, a large part of surface area which has been developed just to supply the body with oxygen is wasted. Our female ancestors fainted so often mainly because they could not breathe deeply.

The lungs are never really empty. They are like a rubber balloon whose sides are never stuck together, but always have a little air in them. No matter if you breathe out with all your might, there will still be some air left. But if the balloon is pricked, the air escapes and the balloon collapses. When a lung is pierced, by a gun shot or a stab, it collapses in the same way, and can no longer trap the life-giving air. But if the hole is mended quickly, the victim may get well

What Happens When Drowning Occurs?

When a man drowns, he dies for lack of oxygen. He can be saved if he is rescued soon enough and simply forced to breathe again. Nothing is the matter with his lungs, but the water in them must be replaced by air. Machines called pulmotors can pump air into the lungs. But since they never seem to be handy when the drowning occurs, it is wise to learn how to pump the water out of the lungs, and air into them, by the hand method which is always ready for use in emergency. In our story about "First Aid" we have told how to do this.

Only for a moment does a drop of blood coming to the lungs for oxygen remain in any one spot in the capillaries. Yet this second is time enough for it to pick up all the oxygen it can carry. The thin walls of the air sacs, just like the skin of a balloon that has been blown up, become even thinner when they expand. In fact, they are only one cell thick, and it is an exceedingly flat cell at that. The walls of the tiny blood vessels that surround them are just as thin. This makes it very easy for the oxygen in the lungs to pass into the blood.

How Blood Gets Its Color

In the blood the special oxygen carriers are ready to receive it. These carriers are the little red corpuscles (kôr'pŭs-'l), which contain a special substance that holds iron. This substance, haemoglobin (hē'mô-glō'-bĭn), takes the oxygen to its bosom, as it were; for it combines with the oxygen and turns it and its own self into another substance, the bright red oxy-haemoglobin that gives its color to the blood. In this form it travels around the body, furnishing the cells with oxygen.

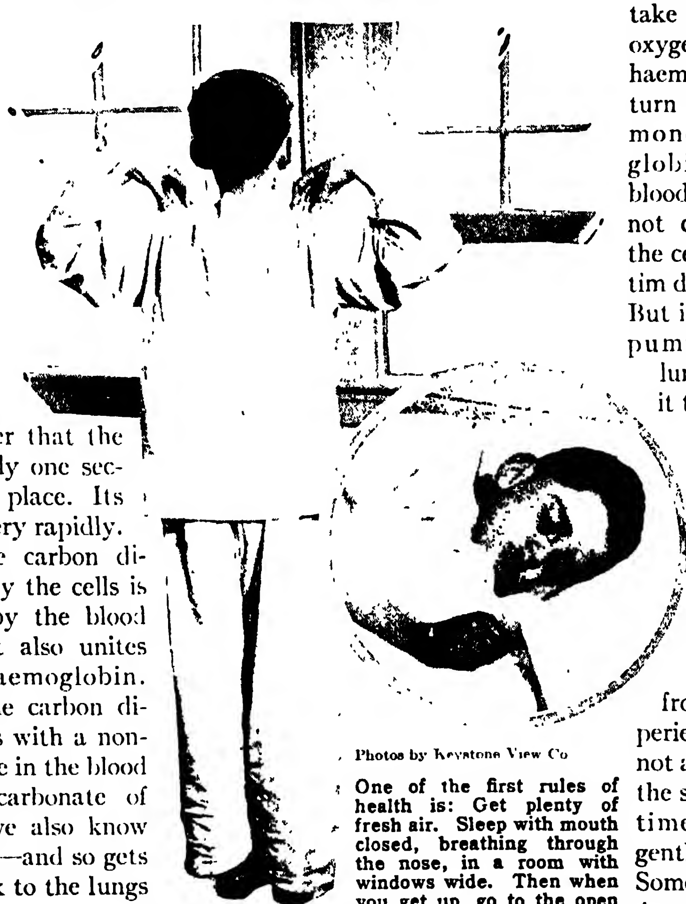
Now since it is in a chemical combination, you might think it difficult for the oxygen to free itself, so as to be breathed in by the cells. Not at all. This is a very special kind

of combination with very special powers. When the oxy-haemoglobin meets any carbon dioxide (dī-ŏk'sīd), the waste product of oxidation, or any lactic acid, the by-product made in the muscles, or even any plain salt, it immediately changes back into oxygen and haemoglobin. The oxygen is freed, and is taken in by the cells. Change of temperature can also free the oxygen from its haemoglobin. When the blood becomes hot, the blood corpuscle loses its oxygen even more quickly. So it really does not matter that the blood stays only one second in any one place. Its work is done very rapidly.

Some of the carbon dioxide formed by the cells is carried back by the blood corpuscles. It also unites with their haemoglobin. The rest of the carbon dioxide combines with a non-living substance in the blood and forms bicarbonate of soda—which we also know as baking soda—and so gets a free ride back to the lungs in that way.

In the lungs, the same thing happens as in the tissues, but in the opposite direction. The blood loses its carbon dioxide, which has freed itself both from the haemoglobin and the bicarbonate, and takes up the oxygen which has seeped through from the lungs. And this exchange of gases, in the tissues and in the lungs, goes on as long as the lungs can breathe, or the heart pump the blood.

Sometimes the lungs breathe poison gas. The gas that comes from the exhausts of automobiles and the gas that we use for lighting and cooking contains poison. This poisonous carbon monoxide (mŏn-ŏk'sīd) has a peculiar power of dealing death to all the animals that breathe it. It unites with the haemoglobin of the blood corpuscles with which it comes in contact 150 times more rapidly than oxygen does! That means that a very small amount of this gas can easily take the place of the oxygen in the oxy-haemoglobin and can turn it into carbon monoxide haemoglobin. Then the blood corpuscles cannot carry oxygen to the cells, and the victim dies for lack of it. But if pure oxygen is pumped into the lungs soon enough, it takes its place in the blood corpuscles, and is even dissolved in the blood itself; and so it reaches the cells in time to save them.



Photos by Keystone View Co

One of the first rules of health is: Get plenty of fresh air. Sleep with mouth closed, breathing through the nose, in a room with windows wide. Then when you get up, go to the open window, straighten your shoulders, thrust out your chest, and fill your lungs full of the fresh morning air.

You know from your own experience that we do not always breathe in the same way. Sometimes we breathe gently and lightly. Sometimes we snore. At other times we gasp. When we are frightened or excited we breathe quickly. When we have been exercising we breathe fast and deeply. And when we are quiet and do not think about it at all, we breathe quietly and regularly.

It is the brain that regulates all this by its control over the muscles. But it is not the "higher part" of the brain, the part that sees and feels and thinks, and has to sleep and rest in order to work again. It is a "lower part." Our breathing must never stop; so where should we be if the master that controls it took a nap? The "lower

part" of the brain, which takes care of our breathing, never sleeps. It works steadily day and night, twenty-four hours a day to keep us alive.

The Spot That Controls Our Breathing

The important spot in the lower brain which controls our breathing is called the respiratory (rē-spīr'ȧ-tô-rĭ) center. It is very, very sensitive, and in that lies the secret of its power. Run a hundred yards and see what happens to your breathing. It comes more quickly and more deeply. The respiratory center has done its work, and has at once set the respiratory muscles to working harder in order to fill the lungs with the greater supply of oxygen that the body now needs.

Whenever we need more oxygen the center knows it—not by the lack of oxygen in the blood that streams through it, but by the presence of carbon dioxide. It is to carbon dioxide and lactic acid, the by-products of work and exercise in the cells, that the center is so sensitive. There is always some carbon dioxide in the blood, because our cells are always working and oxidizing. They supply heat and movement to the body, and at the same time are kept very busy repairing their worn-out tissues, for you remember the body is a wonderful self-repairing machine. Thus the center is always steadily sending messages to the muscles, and we breathe quietly and regularly.

How Often Do We Breathe?

Grown men breathe about sixteen times a minute. Boys and girls breathe from twenty to thirty times a minute, and tiny babies about forty times. The younger people need to breathe more rapidly because their cells, besides working and repairing, are also very busy growing. For that reason, the lungs have to work faster to supply a greater amount of oxygen.

Now we have said that when you have been running, your muscles have given off more carbon dioxide and lactic acid into the blood, and that just as soon as the respiratory center in the brain "feels" these chemicals passing through it, the center tells the muscles that control our breathing to work faster. But that is by no means all. Suppose you keep on running. Then the center feels even more carbon dioxide and lactic acid in the blood, and it sends out messages to still other muscles that do not usually help in our breathing—the tiny muscles of the "wings" of our nose, those of the delicate vocal cords in the voice box, and the muscles of our throat. Did you ever notice your nostrils spreading when you were breathing hard? These new muscles widen the passages for the air to reach the lungs more easily. When the messages are coming thick and fast, we begin to pant, and sometimes to gasp for air.

And that is not yet all. Even before you begin to run, your breath starts to come faster. That is because you know—with the higher brain—that you are going to run and so to need more oxygen. The higher brain sends a call to the lower brain, and the lower brain relays it to the muscles around the lungs; and before you know it you are breathing faster just because you think you are going to run. If you change your mind, your breathing soon gets slower.

Why We Gasp for Breath

Even a pain, or any strong emotion, will change your breathing. The change is made in the way we have just been describing. The nerves of feeling carry the message up to the respiratory center, and the order goes out to breathe faster. When we are violently excited, our breath comes in pants of fear or joy. When we are hurt, we gasp.

Now all these things go on without our thinking about them. At least it is very seldom that we think about our breathing. But when we do, even the thinking changes the breathing. Have you ever noticed how hard it is to breathe naturally when you are thinking about how to breathe? Have you noticed it while you were reading this story about breathing? There is a tale about a centipede who had always managed all his hundred legs perfectly until one day he fell to wondering how it was that he did manage so many legs at once. He sat down to think about it, and that was his Waterloo:

"He lay within the ditch all day
Considering how to run!"

What is the matter with this small boy? It is not bedtime yet, and he has plenty of fresh air to breathe; yet he is yawning vigorously. The trouble is that his skin cannot "breathe," for part of his body is confined in an airtight chamber. When he gets out he will wake up and be lively again.

There are a good many things that we do best when we are not worrying about how we do them.

The same center in the brain can also slow down our breathing, and sometimes even stop it altogether for a few seconds at a time. Ducks stop breathing when they are held head downward, or when they dive. We do not breathe when we swallow, or, if we are swimmers, when we dive. Can you figure out what happens to the center to make it stop the work?

Do You Breathe When You Eat?

When the duck plunges its head down into the water of its pond in search of food, and when we swallow the food we have been chewing, the same thing happens. The center gets messages telling it to stop. In the duck the message comes from its inner ear, and in us from the throat muscles. It would be dangerous to the duck if he breathed in water with his food. And we should choke if the food stuck at the top of the windpipe instead of rolling down the food passage.

A boy diving down to the bottom of the swimming hole in search of pebbles can hold his breath. He has learned that if he breathes deeply a number of times before he dives, he can stay under for a long time. What has happened in the center? After the boy breathes deeply four or five times, he gets rid of a great deal of the carbon dioxide that has been formed in his cells. So for a few

moments there is very little in the blood that streams through the center, and it can go slowly with its work. But as soon as it begins to feel more carbon dioxide, it is up and working hard again, sending out dozens of messages. And try as he will, the little boy can hold his breath no longer. He has to come up.

A good many people who try to climb a high mountain get sick before they are halfway up. They feel dull and headachy, and their lips turn blue. They may even be too weak to move. Why?

The higher we get above sea level, the less oxygen there is in the air. At 5,000 to 10,000 feet, a person who is used to living on the plains or near the sea cannot get all the oxygen he is accustomed to, and his body may well show these distressing signals.

How to Get Used to High Altitudes

But if he stops there, rents one of the little tourist cabins, and rests quietly for a few days, he will soon be well again—that is, if he is a normal, healthy person. For the body is an adjustable machine. It now starts working in a different way to make the best of these new conditions. The heart beats faster to send a greater surge of blood through the body in less time. The respiratory center, feeling so much carbon dioxide and lactic acid streaming through, works at full force. The man begins to breathe quickly and deeply, and soon he has enough oxygen to start walking again.

If he decided to stay for a whole summer, he might easily become a good mountain climber. For the blood corpuscle factory in his bone marrow would soon be turning out more and more corpuscles, each with its share of oxygen-snaring haemoglobin, to pick up even the tiniest bit of oxygen present in the lungs. He would soon be as well and happy as a mountain goat. But when he came down to sea level again, the extra blood corpuscles would disappear, his heart and lungs would no longer work so hard, and he would breathe as he had before he tried the grand sport of mountain climbing.

Now here is something that may surprise you. But even though it is true, do not let it make you love fresh air one bit less, or think it one bit less important. Why do we grow flushed and sleepy, and even headachy, in a stuffy room? Is it because we have used up too much of the oxygen in the air? Or because the air contains too much carbon dioxide?

Not at all! The oxygen supply in stuffy rooms never gets too low for proper breathing. Nor does the carbon dioxide get high enough to hurt us. The reason for our sleepiness is something entirely different. It has nothing to do with the lungs, but with the skin!

Now remember, stuffy rooms are just as bad as ever. If you will hate them just as much as before, we will go on with the story. Maybe it will make you hate them even more when you know the truth.

You know how pleasant it is to go driving on a hot, sultry day. The moist, hot air around your body is replaced every second by cooler, drier air. It "sets you up." This is the secret of the pleasure of riding in an open car.

The Body's Wonderful Heat Regulator

The skin is the wonderful heat regulator of the body. When it is too cold, it does not let the warm blood come to the top and be wasted. When it is hot, the blood comes to the surface and flushes the skin, and heat is given off to the air. The sweat glands, too, start busily manufacturing the liquid which is given off by evaporation. This also cools the skin.

Now you can guess what it is that happens in a stuffy room to make you dull and drowsy. Breathed in and out over and over again, the air gets warm and moist. Our skin cannot get rid of its heat and perspiration—especially if we wear tight, heavy clothing—and the whole body feels uncomfortable. It is not our lungs that are uneasy, but the whole outside of us. All we have to do is to open a window, even a little, and the drowsy feeling goes. The air begins to circulate again. New, cooler, drier air takes the place of the hot, moist air around our bodies under our clothes. So the secret of keeping awake and feeling well is a circulation of air.

Reading Unit No. 11

WHAT OUR RED BLOOD DOES

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Theories about the blood's effect on bacteria, 2–344
The work and travels of a red blood corpuscle, 2–344-45
Where red blood corpuscles are born and die, 2–345
How the blood keeps the body at the correct temperature, 2–347-48
Why we rarely bleed to death, 2–348-49
How we fight germs, 2–349-50

Things to Think About

How is the oxygen which we breathe carried to every cell in our body?
How does food get from a blood vessel to the cells?
What prevents our bleeding to death when we get a cut?
How do phagocytes police the blood stream?

Picture Hunt

Why do doctors take a sample of a patient's blood? 2–344
Which corpuscles in the blood are the largest? 2–346
Why do tuberculosis germs usually settle in the lungs? 2–347
Why does the blood come out of even a slight pin prick? 2–348
Why are objects placed in the mouth or stuck into the skin sometimes dangerous? 2–349

Related Material

What diseases may be caused by bacteria? 2–21
How does the blood travel to all parts of the body? Frontispiece, Volume 2
How would you give first aid in a case of bleeding? 2–403, 405-6

Leisure-time Activities

PROJECT NO. 1: Learn how to stop arterial and venous bleeding, 2–405-6.
PROJECT NO. 2: Learn how blood moves in an animal by studying under the microscope the tail of a live fish.
PROJECT NO. 3: To learn where red corpuscles are made, smear some marrow from a cow's leg bone on a slide and study it with a microscope, 2–345.

Summary Statement

The red corpuscles carry oxygen from the lungs to all parts of the body; the plasma carries food, wastes such as urea and carbon dioxide, hormones and some enzymes, and also corpuscles. Lymph around the cells allows dissolved food to pass from cell to cell or from blood vessels to cells.

Since the blood is all-important to the life and health of the whole body, doctors often take a little of it from a sick person and test it to see whether it will tell them what is wrong with the patient. Here such a specimen of blood is being examined in the laboratory under the microscope.

There are various things which can be found out about a person's blood by such tests. We can count the number of red and white corpuscles per cubic millimeter, and discover the percentage of haemoglobin in the blood and its specific gravity, find out how alkaline it is and how fast it will clot, and detect germs in it.

WHAT OUR RED BLOOD DOES

The Endless River Running through Our Bodies Feeds and Washes Every Organ as It Passes on Its Way

EMIL BEHRING was an army doctor. He was also a poet and a "microbe hunter," who spent many years searching for the cure for diphtheria (dĭf-thē′-rĭ-ȧ). And it was his faith in blood that guided him. He thought blood about the most remarkable thing in the body. He had the highest confidence in it. He even grew poetic over it. He used to quote great poets on the wonders of it. And he made up a theory about the blood.

His theory was that there are chemicals in the blood which kill murderous microbes that stray into it—kill whole armies of them. All the while he was saying this he was searching for the cure for diphtheria, until at last he found it, and so saved millions of lives.

Meanwhile the great Russian, Elie Metchnikoff (mĕch′nĭ-kôf), who was working at the Pasteur (pȧs′tûr′) Institute in Paris, had another theory about what kills microbes. He declared that it is the "phagocytes" (făg′-ō-sīt) in the blood that eat up the invading armies of germs. And he threw Behring and the other microbe hunters into an uproar of debate that lasted for a good many years.

In the end it was found out that both sides were right enough, as we shall see.

But before we talk about how the blood protects the body from germs and disease, we had better tell how it carries on its ceaseless traffic, through its system of closed blood vessels, to every part of the body.

The red blood corpuscles (kôr′pŭs-'l) are the ships that supply our countless millions of living cells with oxygen, the gas that helps these little engines to burn their fuel. The corpuscles carry away another gas, carbon dioxide (dī-ŏk′sīd), which is the product of combustion in the engine cells. To bring the oxygen from the lungs, and to take the carbon dioxide back to the lungs, the red blood corpuscles are built in a special way. They are

round, and hollow on both sides. They contain a special substance, "haemoglobin" (hē′-mô-glō′bĭn), which can pick up the gases very quickly and unload them just as fast. Haemoglobin contains iron, and the iron gives its color to the red corpuscles. But a single red corpuscle is not red; it is yellow. Only when the corpuscles sail around together do they give the blood its red appearance. They can do this very easily. For there are five million red blood corpuscles sailing in a drop of blood the size of a pinhead!

The Blood's Cargo of Iron

Iron is heavy. It must be built into the red blood corpuscle in such a way that it will not sink the ship. So the iron is floated on a large, light protein (prō′tē-ĭn) molecule (mŏl′ē-kūl)—the smallest possible bit of protein; there it rides, like an iron bell on a cork buoy. Though their load is heavy, the red blood corpuscles sail easily along through the watery part, or "plasma" (plăz′má), of the blood, stopping only for an instant here and there, to unload their cargo of oxygen and reload their carbon dioxide.

The channels through which the blood flows—that is, the blood vessels—grow smaller and smaller as they go, like the twigs of a tree. Finally they get even narrower than a single red blood corpuscle. It would seem impossible for these ships with their precious loads to get through so narrow a stream. But they do. For the corpuscles are soft and elastic. They wriggle through the tiny blood capillaries, just as a cat squeezes through a hole that looks much too small. Then they go right back into shape again.

Where Nothing Goes to Waste

The red blood corpuscles do not live long. After a few days or weeks—scientists are not sure exactly how long—they are destroyed by the liver or by the spleen. They are thoroughly dismantled. Their coloring matter is used to make the bilirubin (bĭl′ĭ-rōō′-bĭn) and the biliverdin (bĭl′ĭ-vûr′dĭn) of the bile, and even the pigment, or color, of the skin and hair. But our bodies are very economical. The liver cells do not waste the iron, which is so rare that it has been called "the gold currency of the body." They keep it, and send it back to the red marrow in the long bones. The marrow is the factory where the red blood corpuscles are built by the millions. Though a bone looks so hard and solid, it has many little blood capillaries (kăp′ĭ-lā-rĭ), or tiny hairlike veins, running through it to the red bone marrow in the middle. The brand-new red blood corpuscles are launched here, and sail out into the blood stream. They are ready for active service.

But sometimes the marrow becomes diseased. It continues to manufacture blood corpuscles, but these are badly formed and cannot do the work of carting gases well. A person with a diseased marrow grows sick and pale. He is anaemic (á-nē′mĭk). Recently the doctors have found a very helpful and very simple cure for anaemia. They feed the patient a great deal of liver.

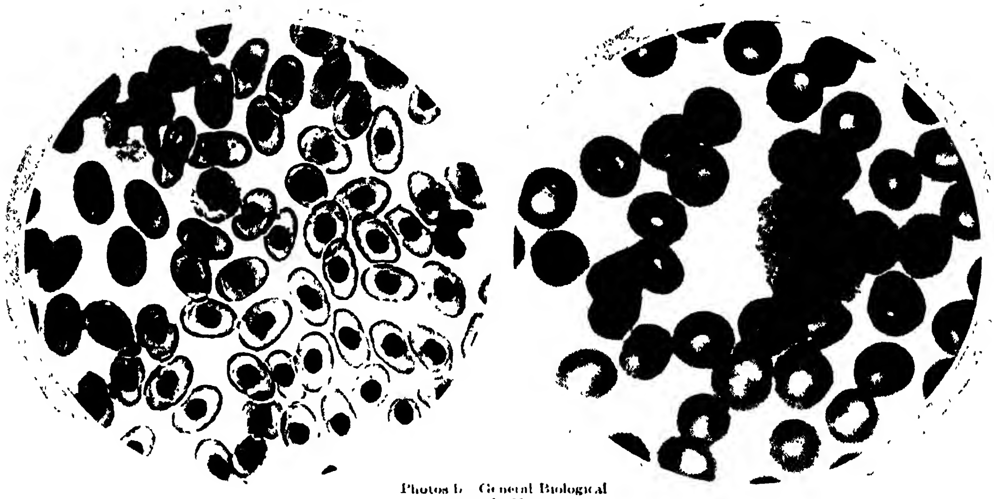
What the Blood Is Made Of

The blood corpuscles, red and white—we will talk about the white ones a little later—make up one-third of the weight of the blood.

The rest of the blood is called the plasma. Most of it is water, as much as 92 per cent. But the 8 per cent of solids present are of very great importance.

You can list most of the solids in the blood plasma yourself. The food stuffs that stoke our living engines and repair them come first. Then there are the waste products, like urea (ū-rē′á), which are transmitted to our exhaust organs, the skin and kidneys. Of organic salts there are many kinds present. One of these is common table salt. That is why the blood tastes salty when you cut your finger and suck it. Certain enzymes (ĕn′zīm) sail around in the blood. They are carried to the cells that need them. Hormones (hôr′mōn), the letter carriers of the body, are forever taking their messages to the different organs, which they regulate so well that the body works as smoothly as a purring engine.

There are proteins (prō′tē-ĭn) in the blood too, and their importance is very great. They help to make the blood clot in a wound. So do the blood "platelets"—little round things that scientists have not quite made up their



Photos by General Biological Supply House

The corpuscles in a frog's blood (left) are oval instead of round like those in human blood (right). The large body in the human blood is a white corpuscle.

minds about. For the scientists are still studying the blood to find out what else this wonderful fluid contains that makes it such a reliable bodyguard.

To stoke the cells, direct the organs, and cart the wastes away, the different cargoes in the blood stream must be loaded right into the cells themselves, and the wastes from the cells must be dumped into the blood again. But the blood has a special channel of blood vessels through which it must flow, and these blood vessels are closed. They cannot touch all the cells in the body. The only places where the capillaries—the tiniest blood vessels—reach nearly all the cells are in the lungs and the liver. In the lungs the cells, thinner than tissue paper, are in contact with the walls of the blood vessels, one cell thick. There, it is easy for the red blood corpuscles to dump their carbon dioxide and pick up the oxygen that seeps through the walls. In the liver, too, it is a simple thing for the cells which are right in contact with the blood to take out the red blood corpuscles whose day is done, and destroy them.

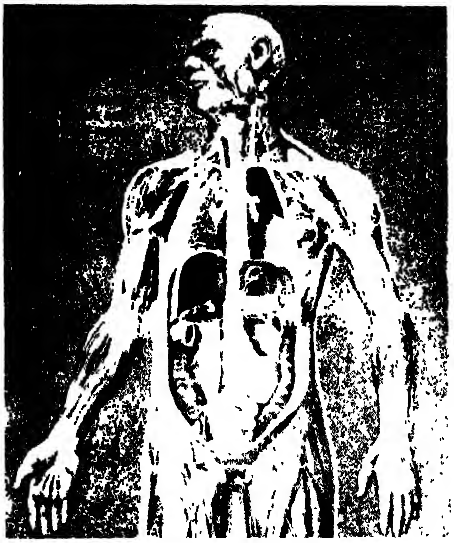
In every other part of the body, where the closed blood vessels reach only some of the cells, there must be some sort of "go-between" for the blood and the cells. The go-between must be able to receive the food and fuel for our engines, as well as the messages that come flocking in, and relay them to all the cells that need them. It must also be able to cart away the wastes produced by our living engines, and ship them back into the blood stream.

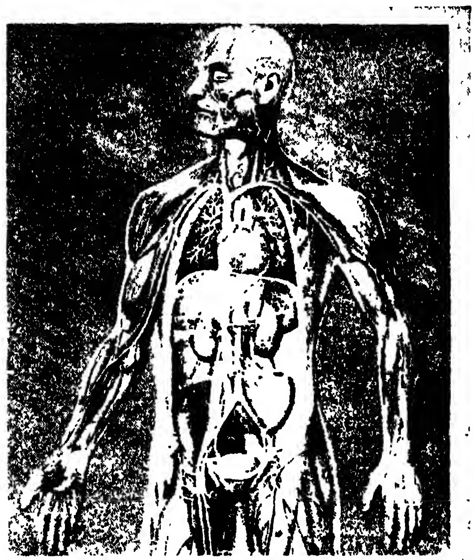
Now the body has such a kindly go-between. It is a fluid called "lymph" (lĭmf). This fluid fills all the spaces between the cells, so that most of the tissues are very much like sponges soaked with lymph. The lymph also bathes the tiny capillaries coming to the tissues. You can see how easy it is for it to act as go-between in loading and unloading stuff from the cells into the blood and from the blood into the cells. The foods and enzymes and messages and water seep out through the capillary walls into the lymph while the blood flows onward. Meanwhile the wastes which have seeped in from the cells are emptied from the lymph into the blood stream, which still flows steadily on. The lymph, reaching all the cells, relays the different cargoes to their proper landing places.

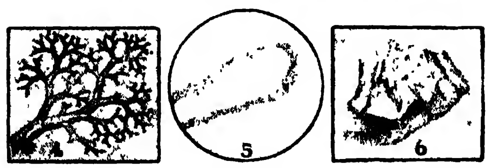
The Ever-present Lymph

Lymph is held in vessels too. It is separated from the tissue spaces by the very thinnest of walls. Just as in a sponge all the holes meet one another, so that all the water can be squeezed out; in this way the vessels of the lymph meet at last. They form large channels, called "lymphatics" (lĭm-făt'ĭk).

All along the way, too, are little lymph







Photos by Clay-Adams Co., Inc

One of the worst diseases the blood and lymph have to fight is tuberculosis. And they do their fighting valiantly; for though in cities nearly everybody is infected at one time or another, comparatively few of us ever know it. The germs may spread through the body by way of the lymph, whose system of vessels and nodes is shown at A above. The lymph nodes, or glands, filter the germs as long as they can to keep the disease from spreading farther. Figs. 1 and 3 show an enlarged section of lymph gland in successive stages of becoming tubercular; 2 is a tubercular gland in the intestine. If the lymph cannot handle the invading germs the trouble may break through into the blood way (6). If that happens it may spread all over the body, through the circulatory system, which is shown at B. Fig. 4 shows the condition of body tissue in miliary tuberculosis, when so many little "tubercles" have grown up around the germs that the clusters look like millet seeds; 5 shows tuberculosis in the wall of a body cavity. The reason why tuberculosis usually settles in the lungs is that they are doubly exposed: all the blood flows through them, and air besides.

"nodes"—or "knobs"—where one form of white blood corpuscle is manufactured.

How Lymph Enters the Blood

Lymph is really nothing but blood plasma that has seeped out into the tissue spaces. It is good stuff and not to be wasted. So there is a special place on each side of the neck where a big lymphatic opens into a large blood vessel and pours all the extra lymph back into the blood stream again, as well as the new white blood corpuscles it has gathered on the way.

The lymphatic system has no pump like the heart to pump the lymph all through the body. Lymph flows only when its vessels are compressed, just the way water squirts from a sponge when it is squeezed. Our muscles, when we move and breathe, press on the lymphatics. The lymph then flows slowly up toward the neck. It does not flow downhill from the pull of gravity, because there are little pockets inside the vessels that catch the lymph and keep it from ebbing back. When it gets to its destination at last, it is sucked into the blood stream, and is no longer lymph.

A Wonderful Heating System

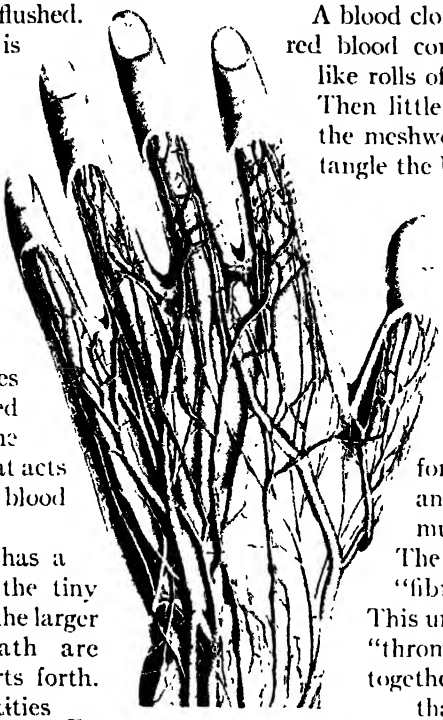
The blood flows on and on, around and around the body. It goes through living factories which are working at full speed. These factories, especially the glands and muscles, give off a good deal of heat. That makes the blood warm, too. It flows on again till it comes to places that are not warm

at all. It warms these up with the heat it is carrying along. Thus all the parts of the body are kept at an equal temperature—98.6° F. in the average person, though people differ a good deal in this respect.

When it is too warm inside the body, the hot blood flows freely into the tiny capillaries in the skin. We become flushed. The heat from the blood is given up to the outside air. The blood also loses some of its heat through the lungs. The air that came in cool and dry goes out warm and moist.

Sometimes the fine armor of our skin is pierced. One of the tiny, closed capillaries is broken open. Blood oozes out. Why do we not bleed to death? It is because the blood soon forms a clot that acts like a cork. It stops the blood from spilling out.

Sometimes our armor has a deeper gash. Not only the tiny capillaries in our skin but the larger blood vessels underneath are pierced. The blood spurts forth. It flows out in great quantities before the blood vessel is tied or a protecting clot is formed. The blood loses its precious red corpuscles. The slashed person, from loss of blood, becomes anaemic. Then the bone-marrow factories immediately begin to work overtime. They manufacture millions and millions of extra blood corpuscles till the loss is made good, and the blood becomes normal again.



You can see some of this network of blood vessels through the stretched flesh on the back of your hand, but should you ever have guessed that there were so many of them? No wonder even a pin prick brings a little stream of blood, and calls forth armies of workers to stop the leak with a clot.

Why We Rarely Bleed to Death

There are some men who, even when their skin is only pricked, keep right on bleeding. Their blood cannot clot. Sooner or later, unless something is done, they bleed to death. Only men have this peculiar disease. It runs in families and skips a generation. Then it is transmitted by a mother to her son.

There are only a few such people. One of them was the former czarevitch, heir to the throne of Russia. Most of us are more lucky. We have all the substances in our blood plasma that make it clot. Even then, it is not a simple matter. The blood must clot outside the body, never inside. For in that case, how could it flow?

A blood clot starts like a fish net. The red blood corpuscles in it are arranged like rolls of pennies, one atop another. Then little white threads appear, like the meshwork of a fish net. They entangle the blood corpuscles. Soon they shrink, pull the corpuscles all together, and form the clot. In that way all the watery stuff, called the "serum" (sē'rŭm), is squeezed out, and the clot is left quite dry.

The stuff of which the meshwork of threads is formed is called fibrin (fī'brĭn), and there are many things that must be present to make it. The first is a blood protein called "fibrinogen" (fī-brĭn'ō-jĕn). This unites with a substance called "thrombin" (thrŏm'bĭn), and both together make the fibrin threads that catch the blood corpuscles. Thrombin is made from thrombogen (thrŏm-bō'jĕn) and lime salts. Fibrinogen helps to make fibrin, and thrombogen to make thrombin.

But the thrombin must not be formed inside the blood vessels or it will form a clot there. Here is where the peculiar little blood platelets come in. They contain a substance that starts the thrombin going, with the help of the lime salts.

To make doubly sure that there will not be any clotting inside the blood vessels, the plasma contains "anti-thrombin," a substance that destroys thrombin. So even if it is formed inside the vessels, thrombin does not get a chance to work, except on very, very rare occasions.

The reason why a blood clot inside our body is very bad is that it floats around and is likely to get stuck fast in some narrow

Photo by Fox Film Co

Disease germs are so tiny that we never see them, and so if we are careless we easily let millions of them get into our bodies—until the white corpuscles have great difficulty eating them all up. The end of a pencil, for instance, is sure to be laden with bacteria, some of which may very well be harmful.

blood vessel. If this happens in some vital organ, such as the brain, the result is always serious and often fatal.

An unbroken skin is a great protection to us. It keeps out many an army of invading germs. But germs are everywhere, in the air, in our food, on our skins, down our throats. They are the cause of all "catching" diseases. How is it, then, that we are well most of the time?

It is because of our blood.

Behring was right to have so much faith in the blood. And Metchnikoff was also right about the phagocytes, or white blood corpuscles.

How the Blood Makes War on Germs

The blood has many ways of making war on germs. First there are the white blood corpuscles. These are like so many tiny blobs of living jelly that move around and eat. We call them leucocytes (lū'kō-sīt), which is simply Greek for "white cells." There are various kinds of these, and they are made in different parts of the body. Some are made in the marrow of the bones, and some, called lymphocytes (lĭm'fō-sīt)—"lymph cells"—are made in the lymphatic glands. They get into the blood and go to all parts of the body; and they can leave the blood stream itself and go around among the cells of the various tissues.

There are several kinds of leucocytes that are very active in eating up decaying tissue and invading germs. It is these that are named phagocytes, which is merely Greek for "eating cells." They may be called the police of the blood. It is their business and pleasure to make war on any criminal germs that they find invading the body.

These white blood corpuscles are very independent. They are just single cells in the blood stream, but they do not have to go the way the stream goes. They can wriggle against the current when they please, and can go anywhere they like in the body. Now as soon as germs get into the body, perhaps through a cut in the skin, a host of phagocytes set out for the spot. Why they do that, nobody knows; but it is just as if they knew they had enemies to fight. The germs may have some sort of chemical attraction for them.

"Millions for Defense"

Also, it is just as if the blood knew that still more police were needed. The marrow starts making great numbers of phagocytes for war on the enemy. "Millions for defense" might be a good motto for the blood. Very

soon a vast army of new phagocytes is setting off along the blood stream to the scene of war.

There it is a fight to the finish. Either the phagocytes will eat up all the germs, in which case the trouble will all be over, or they will be killed themselves by the toxins (tŏk'sĭn), or poisons, produced by the enemy germs.

But the blood has other weapons to assist the phagocytes. As soon as any germs find a way in, the blood starts forming what we call "antibodies" (ăn'tĭ-bŏd'ĭ), or chemicals that do battle with the enemy. "Opsonin" (ŏp'sŏ-nĭn) is one of these; its name is really Greek for "get ready to eat." And what it does is just to get the germs ready for the phagocytes to eat them easily and in vaster numbers. Then there is "agglutinin" (ă-glōō'tĭ-nĭn), which herds the germs together and so makes them easier for the phagocytes to destroy in quantity. If that is not enough, the blood forms "lysins" (lī'sĭn) at the same time, and these substances dissolve the very germs themselves. And the blood also fights the poisonous toxins thrown off by the germs; for it forms "antitoxins" (ăn'tĭ-tŏk'sĭn) which unite with the toxins and make them harmless.

Even in their last death struggle the phagocytes are valiant. They may be said to die to save us. For when they are destroyed they leave behind them substances that keep on killing the germs.

Any pus infection, in the merest pimple or the worst sore, is a sign that there has been a war. Pus is nothing but billions of white blood corpuscles that have met death in the war, together with dead tissue and with germs that are still alive and doing their worst or dead and dying. It is the strewn field after the battle. All that is left now is to clean up the mess and build new tissue; and the phagocytes help even in that.

Now when we think that there are countless billions of these tiny warriors rushing to the defense of an infected finger, and fighting to the death with the countless germs there—well, when we think of that, we are simply lost in amazement at the marvelous way we are made. We can find no words for it. It is as amazing as the countless stars in heaven.

Why Some People Never Have Infections

Of course the blood does not always win the battle. Sometimes the germs win. Then we may have to look out. We may have to cut off the infected finger, to keep the war from spreading all through the body. Even an arm or leg may have to go. And if the germs are deadly, and invade a vital part of the body, we may die. But the blood always does its best; and the way to help it is to keep always in such good health that it can fight hard. The main reason why one person is always having an infection of some sort while another is nearly always well, is simply that the well person keeps his blood and his whole system in "tone" by following the simple rules of health.

We are all exposed to germs all the time; when they do not hurt us it is because we are in "tone" to fight them every minute. Usually the blood wins the fight, and in most cases so easily and quickly that we never know there has been any fight at all. For dangerous infections we now have drugs, such as penicillin (pĕn'ĭ-sĭl'ĭn), to help in the fight.

Reading Unit No. 12

WHY WE HAVE TO EAT

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How the X ray shows us what happens to the food we chew and swallow, 2-353-58

How the stomach churns the food, 2-354-55

How enzymes digest our food, 2-355

How chemical messengers aid digestion, 2-357

The work of the small intestine, 2-357-58

Things to Think About

By what means is food pushed along the food tube?

Why is the digestion of food necessary?

What chemical changes does food undergo in the stomach?

What "tells" digestive glands to pour out their secretions?

How does food in the small intestine get into the blood stream?

Picture Hunt

How can we know exactly what happens to the food we eat? 2-354

In what part of the trunk are digestive organs located? 2-352

Why can the small intestine, although very long, occupy so little space? 2-352

Where is saliva made? 2-355

Why is the lining of the stomach very important? 2-356

Related Material

Why do we sometimes grow sleepy after a big meal? 2-379

Why is it bad to exercise after a meal? 2-379-80

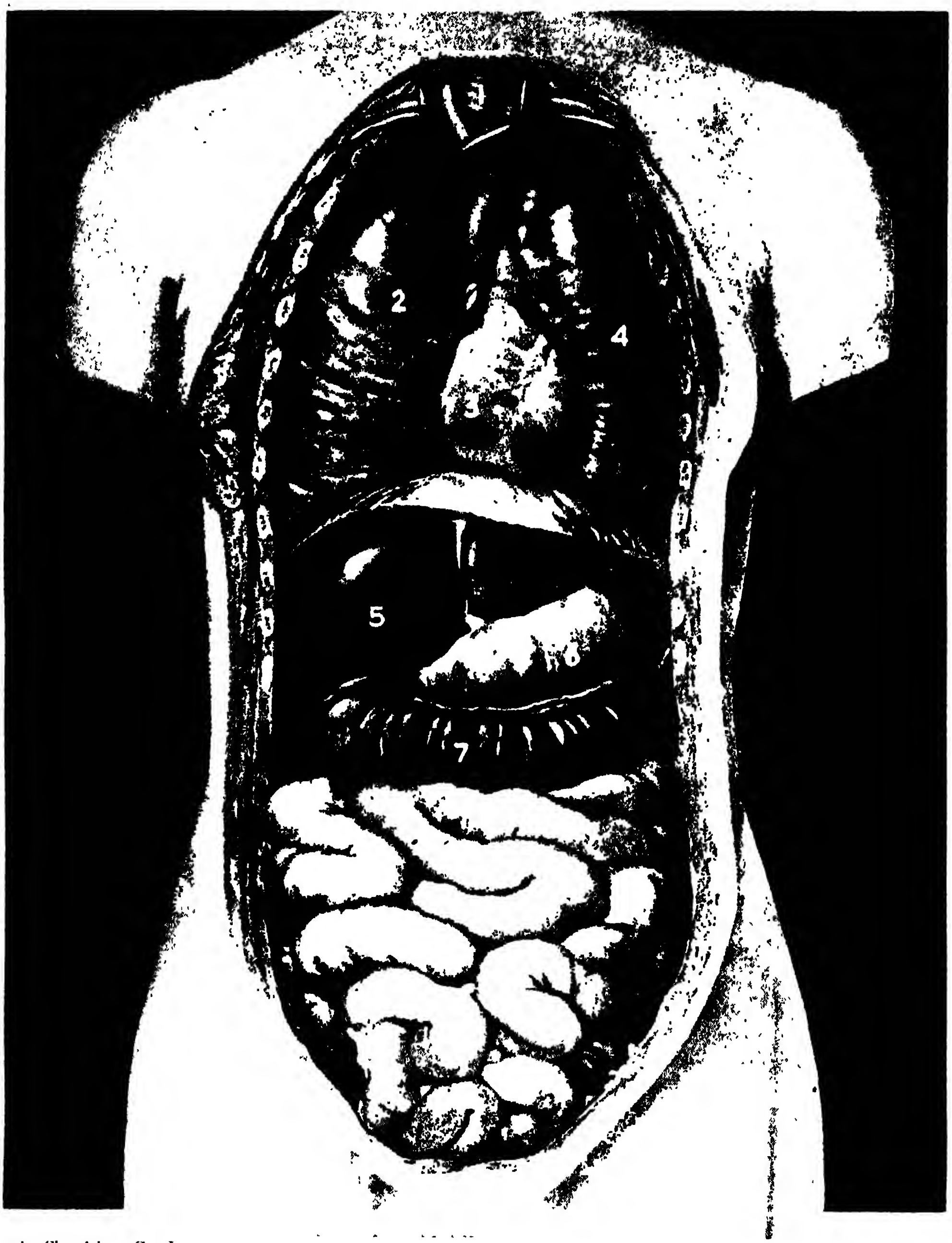
Leisure-time Activities

PROJECT NO. 1: Try to get an old X-ray film of the digestive tract from your doctor. Display it for study against a window in your schoolroom. Try to get a variety of X rays showing other parts of the body, 10-495.

PROJECT NO. 2: To learn how saliva digests starch, add water to some cold boiled starch in one test tube, and saliva to starch in another. Keep them warm for a few minutes; then heat with Benedict's solution. When Benedict's solution turns red it indicates that a simple sugar is present. Does starch turn Benedict's solution red? 2-355-56

Summary Statement

X rays show us that food is pushed and churned in the digestive tube. Mixed with the food are enzymes which digest the food so that it can pass through the villi of the small intestine into the blood stream.



Photos by Clay-Adams Co., Inc.

The upper part of the trunk, above the diaphragm—that arched muscle you see extending across the middle of the body in this picture—is given over to the organs of breathing and circulation. You can pick out these organs of the chest, or thorax, here: the trachea (1), the lungs (2, 4), and the heart (3). Below the diaphragm, in what we call the abdomen, are the organs of digestion. The food passes through the thorax as fast as it can, down the gullet and into the upper end of the stomach. You can see the large part of the stomach (6), with the two parts of the liver (5) lying against it. The pancreas is just back of and below the stomach. From the stomach the food passes to the small intestine (8), where the tiny, innumerable fingers of the villi comb the usable elements out of it. Then it passes into the ascending colon, which you can just see along the lower left side of the picture; then into the transverse colon (7); then at last into the descending colon, a bit of which shows at lower right; and so into the rectum, which does not show here.

People all over the world and in every age have to eat. And luckily they usually enjoy it, if they can get the food they want. For Nature has seen to it that what is so necessary to us should be pleasant.

WHY WE HAVE *to* EAT

And What Happens to All the Food That We Swallow and Forget

YOU are going to be a young medical student for a while. You are coming to a class in the X-ray room. We have an experiment to make.

The room is darkened, and the silver-plated machinery in it shines dully. Along one wall is a sort of cabinet with a small screen attached to it by a curved black handle. That is the fluoroscope (flōō-ŏr'ō-skōp), an X-ray machine that reflects pictures on a special screen. It will show you pictures of all sorts of things inside your body. But it will show only things that are "radio-opaque"—that is, of things that the X rays cannot penetrate. It will never show you the ordinary food you have put in your stomach. If you put bismuth (bĭz'mŭth) into your stomach, however, it will show that very well indeed. So we have two "meals" of bismuth for two of the class; and we are going to see exactly what happens all down the digestive tract when someone eats one of the "meals" and when someone drinks the other.

This bismuth is a white powder. In one "meal" it is mixed with just a little water, to make a sort of paste. In the other there is plenty of water to make it look like milk.

We will try the solid bismuth first. One of you must stand between the screen and the cabinet. Take the bismuth and be ready to eat it. We will start now—on goes the current. Look how the screen shines! See how it shows the bones of the jaws, and the teeth—the gates of the body. The eyes, the nose, and the tongue with its regiments of tiny taste buds are standing guard over these gates to let only good food enter. Once the food is in, however, the teeth start on their work. They are the knives that cut it, and the millstones that grind it. Chewing is the first step in digestion, and a very important one.

Begin to eat the bismuth slowly. Now swallow some. You know that the first part of swallowing is voluntary, that is, you begin it by an act of will. The higher brain sends a message to the muscles of the lips, the cheeks, and the tongue. The respiratory center in the brain, at the same time, sends a message to the top of the windpipe and the

voice box, and tells them to close. The food is pushed back over the base of the tongue, which forms a convenient slide for it to roll down. Then the lips, the muscles of the cheeks, and the tongue itself push the food safely past the rear opening to the nose and the top of the windpipe, and on into the pharynx (făr′ĭngks), with its "pressure pump" for swallowing. That is the end of the movement that you feel when you have swallowed. But it is not the end of the trip for the food.

Just keep watching the bismuth. It has touched a sensitive point in the wall at the top of the gullet and a message is sent to the lower brain; the brain now starts to work the muscle of which the gullet is made. Just below the bismuth the gullet relaxes, while just above, it contracts. Now the same thing is happening a little farther down. The bismuth has touched another sensitive point. And now the same thing is occurring again at the top, where another swallow of bismuth has come into the gullet. There is a whole series of "waves of contraction," very much like the movements of a snake which has swallowed an animal bigger than itself. This wavy action is called "peristalsis" (pĕr′ĭ-stăl′sĭs); it goes on all along the digestive tract from the gullet through the large intestine.

Photo by Battle Creek Sanitarium and U. S. Dept. of Agriculture

Here is a girl who has taken a meal of bismuth and is thoroughly enjoying the results. Of course you cannot see your own tongue and gullet very well through the fluoroscope, but as soon as the food gets far enough down for you to lean over the top of the screen, you can watch it nearly as well as the doctor can. This particular machine has a marvelous arrangement called an orthodiagraph by means of which the X-ray picture is traced directly on paper instead of being recorded on a photographic negative that has to be developed.

The bismuth took about eighteen seconds to reach the stomach. You can see that the stomach is just an enlargement of the digestive tube. In this baglike enlargement we can store food for a few hours; so, you see, it saves us the trouble of eating all day long.

Now let us see what happens when we drink. Will some one else take the other bismuth meal and stand in front of the screen? Now drink it down. Note the difference in the gullet. It remains relaxed. There is no movement at all, and most of the bismuth is already at the bottom, next to the closed opening of the stomach. Now watch! See the strong wave of contraction that passes down the gullet and forces the liquid bismuth into the stomach. It took exactly four seconds to get there!

How the Stomach Churns the Food

Next, we shall turn our attention to the stomach. Notice that there is no wave of contraction along the upper part—only a steady pressure of the walls on the food to

push it downward. The rhythmic waves of contraction begin at the middle, and travel slowly downward. Only three or four of these waves force the food downward, and little by little it is emptied into the small intestine, where it continues on its way. The stomach becomes more tubular in shape, instead of baglike, as it empties. The whole work takes from about three to five hours. The stomach is then about ready for the next meal, and if it doesn't get one, it will soon cry out, and we shall feel the pangs of hunger

Well, lights on and time out! We may now discuss the chemical changes that take place in the food as it travels from mouth to intestine; they will prepare it to stoke the cells of the body.

There are four glands which manufacture saliva for our mouths. One lies under the tongue and one in the neck under the jaw; the two largest, called parotid glands, lie one in either cheek, just below and in front of the ear, as shown in this picture. Both the main part of the parotid gland (2) and its little "auxiliary" (1) lie between the cheek and a flat muscle band (4). They send their saliva to the mouth through the duct at 6; 3 is an artery.

To get the food ready for the cells to use, it is not enough merely to mash it up into a very fine pulp. It must be changed into a form in which it can seep through into the cells and in which they can use it. That is what we call digestion. So all along the road that the food slowly travels in the digestive tract, there are special factories, or glands, that manufacture digestive juices, which have the power of changing food into simpler, soluble substances.

The Mystery of Enzymes

These juices contain very strong chemicals that act on the foods in a peculiar way. And though the scientists have studied them for years and years, and know exactly how they work on every kind of food, they have not yet found out what these chemical "enzymes" (ĕn′zīm), as they are called, are made of. The way to tell an enzyme is to see how it works. By watching their actions very carefully, the scientists have found out a number of things about them and hope soon to find out a great deal more. They know enzymes to be substances that never seep through animal tissue, and they never work in a dry form, but must be wet. Each enzyme works on only one kind of substance. The enzyme that acts on starch cannot deal with fat, and the enzyme that handles fat cannot work on starch. We have also learned that enzymes work best at body temperature and are destroyed by boiling. What the enzymes do could all be done without them but only very much more slowly. Starch could be handled in the digestive tract without its enzyme, but it would take weeks and weeks to do the work of a few hours.

There are four digestive-juice glands in the mouth. They manufacture the saliva (sȧ-lī′vȧ) that makes our mouth water. And saliva really is mostly water, for it is made of more than ninety-nine per cent of slightly alkaline (ăl′kȧ-līn) water, with less than one per cent of solids. Of these, there is the sticky mucin (mū′sĭn) that loves to hug the teeth, and so protects the decaying foods with their colonies of bacteria underneath; and there are the calcium (kăl′sĭ-ŭm) salts that also have a fondness for the teeth, and so form an ugly, dark layer of tartar over them. Both of these solids must be brushed away from the teeth carefully and often. Mixed with these is the enzyme "ptyalin" (tī′ȧ-lĭn),

which changes the starchy food we eat, like bread and potatoes, into sugar, without ever being changed itself. That, by the way, is another special characteristic of enzymes. They help to change food, yet never are changed themselves.

As we chew our food, the saliva mixes with it. The more we chew, the more saliva there will be. But anyone can see that in the short time during which the food stays in the mouth and gullet, the ptyalin has no chance to digest the starch. It is in the stomach that the enzyme does its work. That is why it is so necessary to give the starch plenty of saliva in the mouth. It has to last all the way down.

Saliva has other important work to do, besides acting on starches. It helps in rolling the food into lumps that can be swallowed more easily. It keeps the lips and tongue moist. That is more important than you may think. Have you ever tried to talk with a perfectly dry mouth? If so, you know how much we need the saliva for speech. And there is yet one more thing that it does. When it mixes with foods, it dissolves them so that the taste buds on the tongue will have a chance to tell us whether they are sweet or sour, bitter or salt, good or bad. For you cannot taste anything that is perfectly dry. Just get your tongue quite dry, then put a lump of sugar on it, and see.

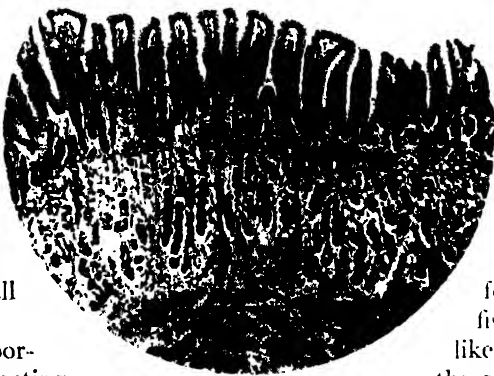


Photo by General Biological Supply House

This is what a cross section of the lining of the stomach looks like under the microscope. The digestive juices are manufactured in the cells of these tiny peninsulas of tissue and at their bases, and escape into the stomach through the ducts, which are the channels between the jutting peninsulas of cells.

The Body's Chemical Factories

Saliva is alkaline. The "gastric juice"—also ninety-nine per cent water—that is made by thousands of little glands lining the walls of the stomach, is acid. Ptyalin works best when its alkali is neutralized by the acid. That happens when the lump of food reaches the stomach. But soon the gastric juice seeps farther and farther into the layers of the roll and makes the saliva acid. Besides, there is also a free acid—hydrochloric (hī′-drō-klō′rĭk) acid—in the stomach. Together they destroy the ptyalin. This may take a long time, however, unless we take violent exercise right after meals. Then, the gastric juice and the free acid enter even sooner and stop starch digestion.

The gastric juice has to mix with the food. It also contains enzymes that help to split foods into simpler substances that are easily dissolved. These enzymes are "rennin," which curdles milk, and "pepsin," which works on other proteins (prō′tē-ĭn), such as those found in foods like meat, eggs, and fish, and in some vegetables like lima beans. Like ptyalin, these enzymes, rennin and pepsin, only partly finish their work before the food moves on into the small intestines.

What makes your mouth water? The sight of candy is enough, sometimes. When you are hungry the thought of food or the smell of it, or the sight of a well-set table sets the factories working. The scientists call the saliva made in this way, just at the suggestion of the eyes, the nose, and even the higher brain, an "appetite secretion" (sē-krē′shŭn). The saliva flows merely at the thought of eating. Did you ever see it drip from a dog's mouth when you held up a meaty bone for him? Anything put into the mouth, especially dry food, will also start the saliva flowing, as we all know. The gastric-juice factories work in the same way. A few minutes after we have begun to eat, they start pouring out their juices as fast as they can.

Yet all of this does not explain why a good-tempered man gets fat. Can you figure it out? Crossness or fear, ill-temper or anger, or even pain, causes our very efficient glands to stop working. Joy and laughter, and all

other pleasant feelings, cause them to work better. This helps digestion so much that almost all the food is broken up and used. None is wasted.

The Ductless Glands

In the stomach there is another thing that makes the glands work. It is not the mere presence of food, as you might expect, knowing what happens in the mouth, but something very different. Scientists have found that some foods, like meat or meat extracts, or partly digested bread, or a substance called dextrin (dĕk′strĭn), start the flow of gastric juice. Starches and the whites of eggs do not. So the scientists tried to find out why some foods make the glands work while others do not.

They discovered a strange thing. Foods like meat extract and dextrin make other glands in the lining of the stomach work too. These glands are not at all like the digestive-juice factories, for they have no ducts or pipes to carry their juices where the juices are supposed to go. They are "ductless" glands, and they form a substance called "gastrin" (găs′trĭn). This gastrin is one of the many hormones (hôr′mōn) in the body. Now hormones are the "letter carriers" that take messages through the blood stream. Each message goes to an exact address. Gastrin travels all over the body in the blood stream, but it delivers its message to one place only. The message reads, "Work harder." The glands obey, and manufacture the juice that contains pepsin.

Starting the Digestive Machinery

The juices of the intestine are poured into it only at the signal of another hormone. This one is called "secretin," (sē-krē′tĭn), and is manufactured when its sensitive factories in the lining of the small intestine feel the acid contents coming from the stomach. Then the secretin is poured into the blood stream to deliver its message. It stops at the pancreas (păng′krē-ăs), which manufactures "pancreatic (păng′krē-ăt′ĭk) juice." It stops at the liver to warn it to secrete more "bile." It pauses at the intestinal-juice factories which are right in the lining of the small intestine. All of these, then, pour their juices into the intestine at the same time. Their enzymes are much more powerful than ptyalin, rennin, and pepsin. By the time they have finished the work of changing food into simpler substances, these digested food stuffs are more or less liquid in form, and are ready to pass into the blood stream. They are all ready to stoke the cells of the body.

We ought to say a word about the bile, though it is not really a "digestive juice" at all. The liver has the task of breaking down the old blood corpuscles (kôr′pŭs-'l). It makes bile with them, using their coloring matter to make the bilirubin (bĭl′ĭ-rōō′bĭn), or the red color of bile, and biliverdin (bĭl′ĭ-vûr′dĭn), or the green. The bile is poured into the intestines, where the bile salts greatly aid and speed digestion.

The Tiny Fingers in the Intestines

The lining of the small intestine is more delicate than the finest velvet. It has a "pile" of the tiniest fingers, so small that they can be seen only through a microscope. Yet each one of these trillions of "villi" (vĭl′ī), as they are called—it is the plural of "villus"—is a delicate mechanism for taking up the simple, digested food stuffs, and transferring them to the blood stream. The food stuffs go right through the cells that line the villi, and some are even changed there, before they go on into the blood.

And now let us go back to the X-ray room again. It is a little more than five hours since we first saw the bismuth enter John's stomach. We are still in time to see the remainder of the meal leave it. So John must get in front of the screen again.

There! See how much like a tube the stomach has become. Watch the food spurt into the small intestine. Note that it does not flow smoothly with each wave of contraction, but that it escapes at irregular intervals in gushes. That is because the ring muscle between the stomach and the intestine is a stopcock that works chemically. The food stuff at the lower end of the stomach is now in a half-liquid state. In this state it is called "chyme" (kīm), and is acid, since gastric juice is acid. The juices in the small intestine, on the other hand, are strongly

alkaline. Now the stopcock ring muscle is very curious. It opens or relaxes only when it feels that it is alkaline on the intestine side, and acid on the stomach side.

There goes another gush! That shows that all the acid chyme that passed through the opening before has been neutralized by the pancreatic juice and the bile. The ring muscle has now allowed some more acid chyme, pushed forward by a wave of contraction, to pass on into the small intestine. There, in its turn, it will be "neutralized"—the acids and alkalis will interact—and it will be digested by those powerful juices.

The Work of the Small Intestine

Let us study the muscular movements of the small intestine. We are already familiar with the rhythmic waves of contraction that we call "peristalsis." But here we find at least twenty feet of intestine that each wave must travel over. As it moves forward, the wave propels the almost-liquid chyme slowly but surely downward toward the large intestine from which the waste products and undigested food will be eliminated.

Look closely again. Do you notice another kind of movement? See how that part of the intestine that was quiet before now seems to form itself, all of a sudden, into a string of sausages. And now this row gives way to another that is forming right in the same place! But another string of sausages is forming lower down, where all was quiet before!

This forming and unforming of the rows of sausage goes on with churning movements that are very necessary in digestion. They make it possible for the food to be thoroughly acted on by all the enzymes in the small intestine. Besides, the churning and mixing, and churning again, lets every bit of digested food get close to the walls of the intestine. There the villi are waiting, with their delicate fingers outstretched, to catch any particle of soluble food that comes near them, in order to relay it on to the blood, and so to the cells.

After twisting and turning for twenty feet, the small intestine reaches the large intestine. The two are again separated by a ring muscle that opens only at certain times.

You can see the junction between the two intestines. Notice how much material has accumulated above the ring muscle. This muscle opens only when it receives a message that a new meal has entered the stomach. It is because John has just eaten a real meal that we can see the bismuth meal passing into the large intestine, on the last lap of its journey.

There it goes! Every time there is a wave of contraction, the ring muscle relaxes, and the food pushes through. But really the contents are not food any longer; they are only waste. All the good, usable food has been taken up by the watchful villi. Biliverdin and bilirubin are still there. They give a brown color to the jellylike mass.

Watch closely. Which way does it go, up or down? First it goes a little way downward. Right there you can see the shadow of something that looks like a worm attached to the large intestine. That is the "vermiform appendix." "Vermiform" (vûr′mĭ-fôrm) means "wormlike." In man, the appendix is a nuisance because it may catch food particles that rot in it and inflame it. In grass-eating animals, the appendix is very much bigger; and it is useful, too, for it helps to digest all the green stuff they eat.

The End of the Journey

Now the food is traveling upward. It is going up the "ascending colon," as the intestine here is called. Then it will start across the "transverse colon," then down the "descending colon," and into the "rectum." From the rectum it will leave the body.

But this movement through the colon takes place only three or four times in twenty-four hours. The mass is made to move by the rapid waves of contraction that start working when a fresh meal enters the stomach.

On the last lap of its journey, the mass loses its water, and becomes almost solid. The water is absorbed by the smooth walls of the large intestine, which in turn secrete sticky mucin and salts. Mucin is a lubricant that speeds the mass on its way. This waste that is left over from the food we eat may be compared to the ashes that are left in the furnace when the fuel has been burned up.

Reading Unit No. 13

HOW WE STOKE OUR HUMAN ENGINE

A star shows vitamins in foods listed	A	Thiamine	Riboflavin	Niacin	C	D
DAIRY PRODUCTS, EGGS						
Butter	*					*
Cheese	*		*			
Cream	*					*
Eggs, whole	*	*	*	*		*
Egg yolk	*	*		*		*
Milk, whole	*	*	*	*		*
MEAT, POULTRY, FISH						
Beef, lean		*	*	*		
Chicken		*		*		
Codfish		*	*			
Fish-liver oils	*					*
Haddock				*		
Kidney	*	*	*		*	
Liver	*	*	*	*	*	*
Mutton, lean		*	*	*		
Pork, lean		*		*		
Salmon	*	*		*		*
Sardines	*	*				*
FRUIT						
Apples		*	*		*	
Apricots	*	*	*		*	
Avocados	*	*	*		*	
Bananas	*	*	*		*	
Blackberries	*	*				
Blueberries	*					
Cantaloupe	*	*	*		*	
Cherries					*	
Currants, black	*				*	
Dates	*	*				
Figs		*	*			
Grapefruit		*	*		*	
Lemons					*	
Oranges	*	*	*		*	
Olives, green and ripe	*					
Peaches	*		*		*	
Pears		*	*			
Pineapples	*	*			*	
Plums	*	*				
Prunes	*	*	*			
Raspberries		*			*	
Strawberries	*		*		*	
Watermelon	*	*			*	
VEGETABLES						
Asparagus, green	*				*	
Beans, lima		*	*			
Beans, navy		*	*			
Beans, snap	*	*	*		*	
Beet greens	*		*			
Broccoli	*	*	*		*	
Brussels sprouts	*	*			*	
Cabbage	*	*	*	*	*	
Carrots	*	*	*		*	
Cauliflower		*	*		*	
Chard	*					
Collards	*	*	*	*	*	
Corn, sweet		*				
Dandelion greens	*				*	
Eggplant		*				
Endive	*		*		*	
Kale	*	*	*	*	*	
Kohlrabi		*			*	
Leeks		*			*	
Lettuce, green	*	*	*			
Mushrooms		*				
Mustard greens	*	*	*	*	*	
Okra	*					
Onions		*			*	
Parsnips		*			*	
Peanuts		*	*	*		
Peas, dried		*	*	*		
Peas, green	*	*	*	*	*	
Peppers, sweet	*	*			*	
Potatoes		*			*	
Radishes					*	
Rhubarb					*	
Rutabagas		*			*	
Soybeans		*	*	*		
Spinach	*	*	*	*	*	
Squash, yellow	*	*				
Sweet potatoes	*	*			*	
Tomatoes	*	*	*	*	*	
Turnip greens	*	*	*	*	*	
CEREALS						
Corn meal, yellow	*	*	*			
Whole grains		*	*			

The table below shows the protein, fat, carbohydrate, and energy values in a pound of certain typical foods.

Food	Protein	Fat	Carbo-hydrate	Energy value
	Grams	Grams	Grams	Calories
Apples, fresh raw	1	2	59	200
Apricots, dried	24	2	303	1,325
Bananas	4	.5	70	300
Beans, dried	100	7	282	1,500
Beans, snap or string	10	1	31	170
Beef, round steak	78	54	0	800
Bread, white	39	9	237	1,185
Bread, whole-wheat	41	14	224	1 185
Broccoli	7	.5	11	75
Butter	3	367	2	3,325
Cabbage	4	.5	18	90
Cantaloupe	1	.5	10	50
Carrots	5	1	37	180
Cheese, Cheddar type	108	146	8	1,785
Codfish	52	1	0	220
Eggs	52	46	3	635
Kale	11	2	21	145
Milk	16	18	22	310
Oranges	3	.5	37	165
Peas, fresh green	14	1	36	210
Pork chops	60	91	0	1,060
Potatoes	8	.5	73	325
Sweet potatoes	7	3	109	490
Tomatoes	4	1	18	100

By the courtesy of the U. S. Bureau of Home Economics

This is cricket, a great popular sport in all English-speaking countries except the United States. Each side has eleven players. Each player goes in to bat, and keeps playing till he is put out. A first-class match lasts for two days. The three upright stakes, or "stumps," form the "wicket." On top of it are laid two strips of wood, or "bails"— one across each pair of stumps. There are two wickets, 22 yards apart. From the one opposite the batsman the opposing "bowler" tries to throw a ball to knock down the bails. If the batsman hits it he scores by running to the other wicket before the ball can be sent by a fieldsman to the wicket keeper— the boy wearing gloves— who will knock off the bails with it. The player behind the wicket is a fieldsman.

Photo by British Information Services

Whether our boys win their game will depend to an amazing degree on the food they eat. Every day they will be careful to drink at least a quart of milk and to eat food from each of the following five classes: 1) raw leafy green vegetables, 2) green or yellow vegetables, 3) fruit or tomatoes, 4) cheese, eggs, fish, meat, or poultry, 5) cereals or bread and butter.

HOW WE STOKE OUR HUMAN ENGINE

This Is the Story of the Way Each Big or Little Organ of the Body Gets Its Fuel and Throws Off Its Wastes

THE cells are the tiny bricks that make up the house of life which is our human body. For the cells form the "tissues," the tissues form the "organs," the organs form the "systems," and the systems form the whole body. But the cells are by no means lifeless bricks. They are filled with the vital jelly called "protoplasm" (prō'tō-plăz'm), which lives and moves and works.

If the cells serve as bricks, they also work like engines, and each engine has its particular job. The cells of the glands manufacture juices. Those of the red marrow, a tissue stowed away inside many of the bones, form the red blood corpuscles (kôr'pŭs-'l). Those of the liver and the spleen destroy these same corpuscles, made just a few weeks before. The cells in the striped muscles move us from place to place. The ones in the unstriped muscles keep our inner machinery going for twenty-four hours a day, three hundred and sixty-five days in the year. Nerve cells carry the messages that regulate the machine as a whole. The cells of the eyes enable us to see, and those of the ears to hear. And so the whole machine ought to go easily and smoothly on its way through life.

Like real engines, the cells must have fuel, and oxygen with which to burn their fuel.

For the fuel the cells use the digested food stuffs made by the stomach and intestines out of what we eat, and carried by the blood to the tissues. From the food they also get the mineral salts which are so necessary for their life and work. They get their oxygen from the lungs. And all of these things, as well as the water we drink or take in with our food, are brought to them by the blood stream which carries its trade into the most distant and hidden parts.

The cells, stoked by the food stuffs, burn, or "oxidize" (ŏk'sĭ-dīz), their fuel to form the energy for their different kinds of work. In the oxidation they give off waste products, such as carbon dioxide. They form other by-products. And they wear away part of themselves, as real engines do. So they have to be repaired.

And here is the wonder of these living machines. Just as they are always breaking down and wearing away, so the cells are continually building themselves up again. They repair themselves. They even grow new daughter cells, or other little engines, when they have to. No other engines in the world can do that. This building up, or repair and growth, scientists call "anabolism" (ăn-ăb′ô-lĭz′m)—which comes from a Greek word and means "heaping up." The tearing down of the cells, during which they work and make heat, is called "katabolism" (kȧ-tăb′ô-lĭz′m)—it too is Greek, and means "throwing down"; and the whole process of breaking down and building up, with everything that goes on in our living engines, all the time and together, is called "metabolism" (mê-tăb′ô-lĭz′m)—in the Greek that means "change."

USE OF FOOD IN THE BODY

PROTEIN—Builds and repairs tissue **White (albumen) of eggs, curd (casein) of milk, lean meat, gluten of wheat, etc.**	**All serve as fuel to yield energy in the forms of heat and muscular power.**
FATS—Are stored as fat **Fat of meat, butter, olive oil, oils of corn and wheat, etc.**	
CARBOHYDRATES—Are transformed into fat **Sugar, starch, etc.**	
MINERAL MATTER OR ASH **Phosphates of lime, potash, soda, etc.**	**Shares in forming bone, assists in digestion, etc.**

Food is that which, taken into the body, builds tissue or yields energy.

Here is a chart which shows at a glance the different kinds of fuel our body-engines need and the sorts of food which contain each kind. It will help us to understand why doctors and careful mothers have so much to say about a "balanced diet."

Turning Food into Fuel

We know how most of the raw materials get to the cells to be used by these combustion engines for their repair and work. The oxygen is brought by the red blood corpuscles from the lungs. The water and mineral salts, traveling around with the blood, seep through the walls of the blood vessels into the cells that need them, without much ado. But the food stuffs must go through certain other changes after they leave the small intestine, before they can become the fuel that stokes our living engines.

At this task of changing the food stuffs into fuel, the liver, a hard-working organ if there ever was one, labors efficiently and well.

First let us see what happens to the sugars after they leave the small intestine. No starches ever get out into the blood. For the foods that were starches when we ate them have been turned into sugars—which of course are all dissolved—with the help of the enzymes (ĕn′zīm) in the digestive tract. These sugars, with some of the other food stuffs, are sent directly to the liver through a special channel called the portal vein. Here they are taken out of the blood by the cells of the liver, changed into "glycogen" (glī′kô-jĕn), an "animal starch," and stored away.

The liver is the body's storage house for glycogen, which is removed only as the engines need it. Then the liver again changes the glycogen back into soluble sugar and ships it out into the blood stream. The liver never lets more than a certain amount out into the blood at one time, and even then only when it gets a special notice through a hormone (hôr′mōn) called "adrenalin" (ăd-rĕn′ȧ-lĭn). For too much sugar in the blood spells danger. It means sickness ahead.

At the same time, the pancreas (păng′krê-ăs) sends another hormone out into the blood. This is "insulin" (ĭn′sû-lĭn). It unloads the sugar from the blood into the cells. If the insulin fails, there is trouble brewing. The sugar is not unloaded, but remains in the blood stream. This is dangerous. The body immediately flies its danger signals to warn us of sickness ahead, and the first symptoms of the disease called diabetes (dī′ȧ-bē′tēz) begin to appear.

By the way, each muscle cell has its own little way of storing glycogen. It would be awkward otherwise. The muscle cells must always be on the alert, waiting for a message

At the left above is a picture of the hard-working liver from below. It is divided into two parts, the right lobe (3) and the left lobe (1). Against the lower surface of the right lobe lies the little gall bladder (2) which holds the bile. The whole lower surface, except the part marked 4, is covered by the wall of the sac-like peritoneum (pĕr′ĭ-tō-nē′ŭm), which lines the abdominal cavity. The picture at the right shows the pancreas and kidneys, and you can tell pretty well how they fit against the liver by the reappearance in this picture of the gall bladder (1) and a cut portion of the liver itself (2). The thickest part of the pancreas (6) lies in the curve of the duodenum (5), which is the beginning of the small intestine. The kidneys, right (4) and left (7), lie on either side of the pancreas; 3 is the great central artery, the aorta.

to contract. Contracting is their work, and it takes fuel. If they had no storage place, and had to wait for fuel to stoke their engines, their motions could never be made in the twinkling of an eye, as they are.

How the Body Stores Up Fats

The fats have a more roundabout route to travel before they get to the liver. They are carried by the blood to the lowest layer of the skin, where they are stored. They are also stowed away in a great layer right over the abdomen. We might possibly say that fat is stored in the body as though it were a savings account. It is put away for a lean day, when the body, through sickness or starvation, will need the extra sum of fat to keep the billions of living engines well stoked and working. But we must not store too much fat for that purpose!

The sugars that are stored as glycogen may possibly be called the body's checking account, to be used conveniently in its every-day affairs. Sometimes when there is too much sugar to use, it is changed into fat, and also put away for a rainy day. No one knows how this is done.

But any great storing or hoarding takes place only when we constantly eat too much. Then we get too fat. As a rule the fats, as well as the sugars, are used up at once. They are taken by the blood from the "fat depots," or storehouses, underneath the skin and are carried to the liver. The liver changes the fats into a form in which they can be used by the living engines all over the body, as fuel to produce heat and work.

The Use of Fats and Sugars

The fats and sugars are used by the cells only for heat and work, never for repair and growth. That is the work of the proteins (prō′tē-ĭn) alone.

In the small intestine the proteins that we eat are broken down into the parts of which they are made. These are called "amino (ăm′ĭ-nō) acids," because the amino part contains ammonia. Though there are many kinds of proteins, there are only about twenty-five amino acids. Of these, five or

six are very valuable to us, for they are the only ones that have the power of repairing the old, worn-out tissue and of building new.

As the amino acid particles travel around the body in the blood stream, the cells select the ones they need for their repair and growth. Then the cells of each of the different kinds of tissue build up their own form of proteins from the amino acid particles.

The rest of the amino acids, not used as building materials by the living machines, are carried back by the blood stream for storage in the liver. Here they are changed and sent out into the blood again. The living engines pick them up, and use them as the fuel to produce heat and work, just as they use the sugars and fat. The protein which we call gelatin does not contain a single amino acid particle which can be used by the body to repair old tissue and build up new. The amino acids of which it is built can be used only as fuel to stoke our engines. But casein (kā'sē-ĭn), the protein found in milk, has all the amino acids that repair our tissues. That is one of the reasons why milk is called a "perfect food."

BOYS

	Age	Weight (Pounds)	Height (Inches)	Chest (Inches)	Head (Inches)
WITHOUT CLOTHES	Birth	7.55	20.6	13.4	13.9
	6 months	16.0	25.4	16.5	17.0
	12 months	21.0	29.0	18.0	18.0
	18 months	24.0	30.0	18.5	18.5
	2 years	27.0	32.5	19.0	18.9
	3 years	32.0	35.0	20.1	19.3
	4 years	36.0	38.0	20.7	19.7
	5 years	41.2	41.7	21.5	20.5
	6 years	45.1	44.1	23.2	
	7 years	49.5	46.2	23.7	
	8 years	54.5	48.2	24.4	
	9 years	60.0	50.1	25.1	
	10 years	66.6	52.2	25.8	21.0
	11 years	72.4	54.0	26.4	
	12 years	79.8	55.8	27.0	
	13 years	88.3	58.2	27.7	
	14 years	99.3	61.0	28.8	
	15 years	110.8	63.0	30.0	21.8
	16 years	123.7	65.6	31.2	

GIRLS

	Age	Weight (Pounds)	Height (Inches)	Chest (Inches)	Head (Inches)
WITH CLOTHES	Birth	7.16	20.5	13.0	13.5
	6 months	15.5	25.0	16.1	16.6
	12 months	20.5	28.7	17.4	17.6
	18 months	23.0	29.7	18.0	18.0
	2 years	26.0	32.5	18.5	18.6
	3 years	31.0	35.0	19.8	19.0
	4 years	35.0	38.0	20.7	19.5
	5 years	39.8	41.4	21.0	20.2
	6 years	43.8	43.6	22.8	
	7 years	48.0	45.9	23.3	
	8 years	52.9	48.0	23.8	
	9 years	57.5	49.6	24.5	
	10 years	64.1	51.8	24.7	20.7
	11 years	70.3	53.8	25.8	
	12 years	81.4	57.1	26.8	
	13 years	91.2	58.7	28.0	
	14 years	100.3	60.3	29.2	
	15 years	108.4	61.4	30.3	21.5
	16 years	113.0	61.7	30.8	

How tall are you? Oh, you must not stand on tiptoe! And how much do you weigh? Do you weigh and measure about the average for a boy or girl of your age? This chart will help you answer that last question; and if there should be anything wrong, now is the time to see what can be done about it. We grow most during the first year, gaining 8 inches in height. After that the gain is four inches, then three inches a year.

But this is very far from meaning that if we just eat plenty of protein we shall keep all our engines going in good order. All the different kinds of food must be present, and just enough of each, to keep the fires burning most brightly. Then all the food stuffs will be wholly burned up in the cells, and fewer kinds of waste products and by-products will be formed.

Besides, there must be certain mineral salts and plenty of water in the cells if these are going to do their best work.

And that is not all yet. There is a wonderful substance called vitamin D, which keeps little children who have not had enough sunlight from getting rickets. It helps to harden the bones, just as the ultra-violet rays in the sunlight do. It also keeps the teeth from rotting. And there are a number of other vitamins that must be present in our foods to keep us well.

Far back in the time of the ancient Greeks the people knew some of the diseases that are caused by the lack of vitamins in the food they ate. But they did not know what caused those diseases, or what cured them. It was only in 1772, when Captain Cook

Photo by Gramstorff Bros

The name of this painting is "The Doctor." How much it tells of the patience and quiet skill of these men who help us fight our battles with the invading armies of bacteria and the things that go wrong with our own body-machines! The patient research scientist in his laboratory, the microbe hunter who experiments on himself, these are among the heroes of the world. And so is every practicing physician who is worth his salt—who uses his mind and spends his energy and takes his great responsibilities seriously.

sailed round the world, that people had the first inkling of how to prevent and cure these "deficiency diseases," as they are called. Captain Cook's voyage has remained famous for two reasons. It was a very great trip, for one thing; and for another, none of his crew were sick with scurvy! They had eaten plenty of oranges, lemons, and limes—and other fresh foods—when they could get them! It was soon an order in the English navy that all crews be supplied with fruit juices. And because they eat lemons and limes—to keep scurvy away—from that time to this very day the English sailors have been called "limeys."

The Mystery of Vitamins

Of course Captain Cook did not know anything about vitamins. He had merely proved that certain fresh foods prevent scurvy. It is only in our own day that we have found out what we know about the vitamins. Even yet we have much to learn about them. That is why we should get our vitamins from natural foods if possible.

There are many stories about the ways in which we found out how the vitamins act, but we shall tell only one of them.

Conquering a Deadly Pestilence

In 1914 a pestilence broke out in the South. Whole villages in South Carolina, Georgia, and Mississippi were stricken with a sickness which started in a flaming rash and ended in insanity and death. The disease was pellagra (pĕ-lăg′rȧ). The government put Dr. Joseph Goldberger to work on the strange malady. Goldberger knew nothing about it, and neither did anyone else, but he was willing to learn.

He made a tour of one after another of the state hospitals in which there was pellagra, and always he used his eyes, his ears, and his brain. He studied the disease among the children in two orphanages in Jackson, Mississippi. He watched what they ate, and what they did not eat, and after a year of this he had two facts: that pellagra is not catching, and that it comes from not getting enough fresh meat and milk.

And sure enough, he cured all the children in the orphanages by feeding them fresh meat and milk every day!

But that was not enough evidence for the other scientists and doctors who were still afraid that pellagra was catching. For they could certainly see how it spread, and they wanted more proof.

A Real Hero of Science

With the permission of the governor of Mississippi, Goldberger took twelve volunteers from among the convicts on a prison farm where there had never been a sign of pellagra. For two months he gave them the regular prison fare. Then for four months he fed them on the sort of food eaten by the poor mill workers of the south. He fed them the "three M's"—white hog meat, meal, and molasses—every single day, with never a taste of fresh meat or milk. At the end of that time, six of the convicts had pellagra.

But even this was not enough proof for the other scientists. So Goldberger took extreme measures. Out of the excretions of the sick "pellagrins," and out of their dead skin and sputum, he made some bread pellets and ate them! He waited a week, and nothing happened.

And then, on May 7, 1916, he had a party. His four young assistants and his wife were there. Every person in the room took the same disgusting meal that Goldberger had eaten alone the week before. Even that was not all. If there was a pellagra germ, it was sure to be in the blood; and so the five daring men and the woman each got a dose of blood from a very sick pellagrin shot into their arms. Science, you see, has its heroes, as well as war!

But nothing happened.

Yet, to make sure, they tried the unspeakable meal for six more times. Still nothing happened.

Then everyone knew that it was not a germ that caused the dread disease, but the lack of a certain substance in the food. Goldberger called the substance a vitamin. We have since discovered many other vitamins.

Vitamin A is necessary if one is to see well in dim light. Without it the eyes, skin, and mucous surfaces cannot do their best work, and children cannot grow properly. Fish-liver oils are very rich in it, as are leafy green and yellow vegetables—like carrots!

We now know that vitamin B is made up of a large number of vitamins. B 1, or thiamine (thī′ȧ-mĭn), often called the morale vitamin, is necessary for sound nerves. Its lack causes poor appetite and low spirits, constipation, a slow heart, a tired feeling, and various nervous disorders, such as beriberi (bĕr′ĭ-bĕr′ĭ). It abounds in lean pork, baked beans, fresh green peas, liver, and whole-grain bread.

B 2, or riboflavin (rī′bō-flā′vĭn), sometimes called vitamin G, is needed for normal growth and to keep the tissues in healthy condition. Liver, kale, eggs, broccoli, baked beans, lean pork and lean beef and milk are rich in it.

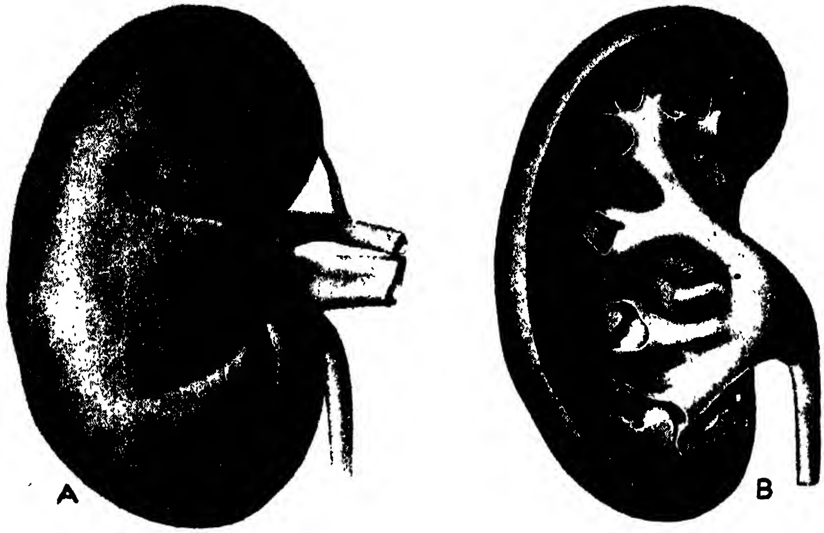
Niacin (nī′ȧ-sĭn), another in the B group, prevents pellagra, though it needs the help of other food elements to do so. Without it people feel weak and tired and gloomy, and have skin troubles and poor digestion. Milk, lean meat, canned salmon, peanuts, and green vegetables help prevent it.

The Anti-Infection Vitamin

It is vitamin C—or ascorbic (ȧ-skôr′bĭk) acid—that prevents scurvy, a disease in which the teeth and bones decay. It keeps all the tissues in healthy condition, prevents certain kinds of anaemia, promotes healthy growth and sound teeth, and helps us resist infections—as do all the vitamins. We get it in turnip greens, broccoli, cauliflower, cabbage, tomatoes, and citrus fruits. These foods should be eaten raw if possible, or cooked only a short time in a very little water in a covered kettle. Never throw away the cooking water.

Vitamin D we have already spoken of. Fish-liver oils are high in it, and of course we manufacture it in sunshine. Everyone needs it.

To do their work the vitamins need certain minerals, especially calcium (kăl′sĭ-ŭm), which makes sound bones and teeth and abounds in milk, cheese, and green leaves. Every child should take a quart of milk a day, and every adult a pint.



This mushroom-shaped organ is a human kidney. The left-hand picture (A) shows how the right kidney looks from in front. The large tube entering it at the middle is a vein, the one above that an artery. The tube, or duct, leading downward is the ureter, which carries off the urinal secretion. In the other picture (B) we can see how this duct is extended and branched inside the kidney, to collect the waste it carries off.

But there is one more important thing to say here. In every bit of food, just as in every lump of coal, there is a certain amount of energy stored up. The energy all came from the same place: from the sunlight, as it shone on the green leaves of plants. Some of the plants turned into coal long ago, some of them turn into food for us right now. The cells of the plants capture the energy and turn it into food for themselves. All other living things get their food and energy directly or indirectly from the plants. The energy in food is released or set free when it is burned, or "oxidized" (ŏk'sĭ-dīz), by our living engines. Some of it is again stored when new tissue is built. The rest is used for work and heat.

What Is a Calorie?

Now the scientists who deal with food measure this energy in calories (kăl'ō-rĭ), in about the same way that jewelers measure precious stones in carats. They have measured the exact number of calories in the various foods. They have also found out just how many calories should be eaten by people doing different sorts of work. The truckman uses more energy than the bank clerk. He should eat more calories of food. Children of different ages, too, must have different amounts of food. Boys of twelve or thirteen, for instance, should have 2,300 to 2,700 calories a day. Girls of the same age should have 1,800 to 2,150. Boys a year or so older should have 2,500 to 2,900 calories a day, girls, 1,950 to 2,250. Men need from 2,500 to 4,500 calories a day, depending on their activity, and women from 2,100 to 3,000.

The body has several "exhaust organs" to throw off the waste products and by-products that come from its working. Some of these we have mentioned already.

One of them is the skin. The sweat glands in the skin average giving off about two pounds of sweat a day. This is mostly water, and it is through the skin that the body gets rid of a large amount of this product of "oxidation." The perspiration also contains

other by-products. But we shall learn more about all these by-products later when we come to study the kidneys.

Another exhaust organ is found in the lungs. They get rid of carbon dioxide, another product of oxidation.

Water and Vegetables in Diet

A third exhaust organ is the large intestine. It gets rid of the waste product from the food we eat. There may be a number of reasons to prevent its doing its work well; but two very common ones are a shortage of water in the diet and too little bulk in the food. When there is not enough water in the large intestine, the waste product there becomes so hard and dry that it cannot move on downward easily. And when the food is not bulky enough it tends to travel in little lumps, instead of smoothly in a large mass. Some of it gets left behind. So besides enough calories, we need a certain bulk in our food, if only to make it large enough to travel well. We can get the bulk easily from such things as leafy vegetables and whole-wheat bread. These add the bulk that we call "roughage" in the diet.

When the intestine is not working well, the waste matter that remains in it forms poisons, or toxins (tŏk'sĭn). These are carried by the blood and do damage to the cells. When there are many toxins sailing around in the blood and playing havoc with our cells we begin to feel it. We get headachy.

The Ellis Island of the Body

H. G. Wells, the English novelist, calls the liver "the Ellis Island" of the body, because "it arrests the undesirable immigrant for deportation. It manacles him, but does not actually remove him." We must tell how the liver does this. It changes the amino acid particles into a form in which they can be used as fuel by our combustion engines. It changes them by taking out the ammonia. Ammonia is then left as a waste product. It is a product of the breaking down of the amino acids, the building stones of protein. Ammonia is formed in the cells, too, when the amino acids are used. It is very dangerous in the body, and if a great deal were left floating around in the blood we should speedily be having convulsions.

But the liver manages very nicely for us. It turns the highly dangerous ammonia into the harmless substance that we call "urea" (û-rē'ȧ). It does the same thing to the poisons or toxins formed in the large intestine, and makes them harmless, too. The liver is a very good detective. It spies out these dangerous aliens in the blood, manacles them, and sends them out into the blood stream, harmless. They are then picked up by the kidneys—and the sweat glands. For the skin does its share to help the kidneys along by getting rid of a little bit of urea.

The Work of the Kidneys

The two kidneys are surprisingly small for the great amount of work they do. They are like large kidney beans, half the size of your fist, each with a long tube attached to it. And it is through these two long tubes that the tiny drops of urine (ū'rĭn), containing water and other by-products and waste products, trickle down to the bladder, about one drop every thirty seconds. Here, in this muscular bag, the drops remain till they are removed from the body.

Let us go back to the sweat glands for a moment. Sweat contains urea and salts, just as the urine does, but in much smaller quantity. These are taken out of the blood by the sweat glands. A sweat gland is nothing but a long tube with an opening on the skin. The bottom part of the tube is coiled and twisted. This twisted part is surrounded by many little blood vessels. The arrangement makes it very easy for the water and salts and urea to seep out from the blood into the sweat gland, and then out on the skin.

A kidney is much more complicated than a sweat gland, but it is a little like one. For it is made of millions and millions of little tubes, or "tubules," which also take up wastes from the blood. Each one of these tubules is longer and more complicated than a sweat gland. That is why, even though they are so small, the kidneys can take up more than all the sweat glands of the skin together.

Reading Unit No. 14

HOW THE BLOOD CIRCULATES THROUGH THE BODY

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How William Harvey in 1616 discovered that the blood circulates, 2-369-70

The heart as a pump, 2-370-72

How the blood moves through the heart, 2-373

Arteries, veins, and capillaries, 2-375-76

What will make the heart beat faster and more powerfully? 2-377-78

How the size of blood vessels is controlled, 2-378-79

Why we feel sleepy after eating, 2-379

Why we blush or turn pale, 2-381

Things to Think About

Why do the hollow chambers of the heart differ in thickness?

Where does blood go from the aorta?

What is meant by "systemic" and "pulmonary" circulations?

Why does your heart beat faster when you run a race?

Why is exercise directly after a meal bad for your health?

Picture Hunt

Why must a surgeon know where every blood vessel is? 2-369

How is the entire body well supplied with blood? 2-371

What provision has the heart for letting blood leave and enter it? 2-374

How is arterial blood able to get back into the heart? Color plate opposite 2-374

Why is surgery of the head very difficult? 2-378

Why are the intestines well supplied with blood vessels? 2-380

Leisure-time Activities

PROJECT NO. 1: Find your wrist pulse and, using a watch, determine what the usual number of beats is per minute. Calculate the number of beats per hour, day, week, month, and year, 2-373.

PROJECT NO. 2: To see the connection between heart and pulse beats, do the experiments on pages 2-376 and 2-377.

PROJECT NO. 3: Examine a goldfish's tail under the microscope to learn what capillaries are, 2-370.

Summary Statement

The blood circulates in the body through blood vessels. The heart pumps blood through these vessels. The heart is very muscular, has four hollow chambers, blood vessels leading in and out of it, and is well supplied with valves to keep the blood moving in one direction.

Photo by Battle Creek Sanitarium

Nowadays skillful surgeons are willing to cut into our bodies in the most bold and amazing ways in order to set right this or that that has gone wrong. They would never dare do this if they did not know all about the course of veins and arteries and the position and function of the heart and other organs. Even so, the patient whose appendix is being removed in this picture would have scant chance to get well if everyone concerned had not learned also how to keep the wound "surgically clean" so that no germs can get in. Notice that doctors and nurses even wear masks to protect the patient from the bacteria that ride on their breath.

HOW *the* BLOOD CIRCULATES *through the* BODY

Round and Round It Goes with a Circular Motion, and in Its Red Stream It Carries Life and Strength to Every Cell in the Body

EVERYBODY knows that the blood flows out of the heart, through the arteries, and into the tiny capillaries (kăp'ĭ-lâ-rĭ), where it gives out its food and oxygen and picks up waste products; then it goes into the veins and back again to the heart. Round and round it travels in a circle, never ceasing for a moment of the day or night. And that is only the beginning of the story.

Yet it took a great man to find out as much as that. He told us about it only some three hundred years ago. The man was William Harvey. In 1616, when he first began to explain his beliefs about the circulation of the blood, there were many strange ideas about the matter, among even the most brilliant scientists. They thought that the heart was a workshop for "vital spirits," and that the arteries ended in nerves! They called them "arteries," meaning "air carriers," because they thought the arteries carried only air, while the veins fed blood to the tissues. There were many more notions current, some of which were even more mistaken. It took plenty of hard work to destroy these notions and to show how the blood really gets around the body. William Harvey was the man who did it.

For ten years, before he wrote down a single word, he tried to show his classes in anatomy at the Royal College of Physicians in London how the heart pumps the blood through the arteries. He told everyone who

would listen to him, and gave anyone a chance to show where he was wrong. When he was sure of the truth, he wrote a book with a Latin title meaning "The Motion of the Heart and the Blood in Animals." He wrote it so simply and clearly that any educated man could easily understand it. He demonstrated that there is only a certain amount of blood in the body, and that the heart is the organ that pumps it. So, at the very instant when the heart contracts, there is a pulse, or beat, in the arteries, because the blood is pushed into them and expands them. Harvey also showed how the blood that flows into the arteries comes back through the veins; and how it then goes to the lungs and back again into the heart. Thus he proved that the blood flows in two circles—to and from the lungs, and to and from all the other tissues of the body, with the heart at the center. But he never actually saw the tiniest blood vessels, the capillaries that carry the blood between the arteries and the veins. His microscope was not good enough for that. He simply had to suppose that there must be capillaries between arteries and veins. And his guess was right.

The Man Who Proved Harvey's Theory

It was left for Malpighi (mȧl-pē′gē), an Italian doctor, to see what actually happens. With his microscope, a much better one than Harvey's, he saw the tiny blood corpuscles flowing through the capillaries. It seems a pity that Harvey, who had been dead four years, could never know that his point was proved.

The heart is an extraordinary kind of pump. It is the central power house of a large transportation system, sending large supplies of fuel, raw materials, oxygen, heat, and other things to the cells, and clearing away their waste products.

Housed in the closed crate of the chest cavity, the heart fits between the lungs, slightly to the left of the middle line. It is triangular in shape, and its tip or apex points downward to the left. Like the lungs, the heart has its own special bag, the pericardium (pĕr′ĭ-kär′dĭ-ŭm). As its name indicates, this bag surrounds the heart. Strong, fibrous, and attached below to the diaphragm muscle, it keeps the heart from getting too big each time it is gorged with blood. Lined with smooth cells, and filled with lymph, the pericardium also prevents friction every time the heart thumps against the chest wall. That happens about seventy times a minute, twenty-four hours a day—or about a hundred thousand times every day.

How the Heart Is Constructed

The inner layer of the heart is very smooth, and is made of delicate connective and elastic tissue—"endocardium" (ĕn′dō-kär′dĭ-ŭm), it is called. This lining has not the slightest ridge or groove in it to catch at the blood that the heart is propelling onward. Here too there is no friction to mar the perfect work.

The heart is a very tough organ, built for hard work. Its business is to pump the blood that supplies our billions of cells through its closed channels of transportation to the farthest and most hidden corners. To insure plenty of strength, the middle layer of the heart is made of myocardium (mī′ō-kär′dĭ-ŭm). This is the heart muscle tissue, surely the hardest working stuff in the body; the first to start working and the last to lay down its task when we die.

When we were talking about muscles, on another page, we said that the heart was made of a special kind of muscle cell. It is striped muscle, and yet it is not under the control of the will, which goes to sleep on occasion. This means that it does a great deal of hard work without our ever thinking about it.

The Muscles of the Heart

There is another peculiar thing about heart muscle, which makes it different from any other muscle in the body. Its fibers or cells are not separated from one another. They fit one into another like the strands of a net. These fibers cannot be teased apart by the very finest needle. When one fiber gets a message to work, all the other fibers begin to work too. Each little fiber must work as hard as it can, and heave with all its might. That is what makes the heart contract and bump against our ribs. It moves and twists

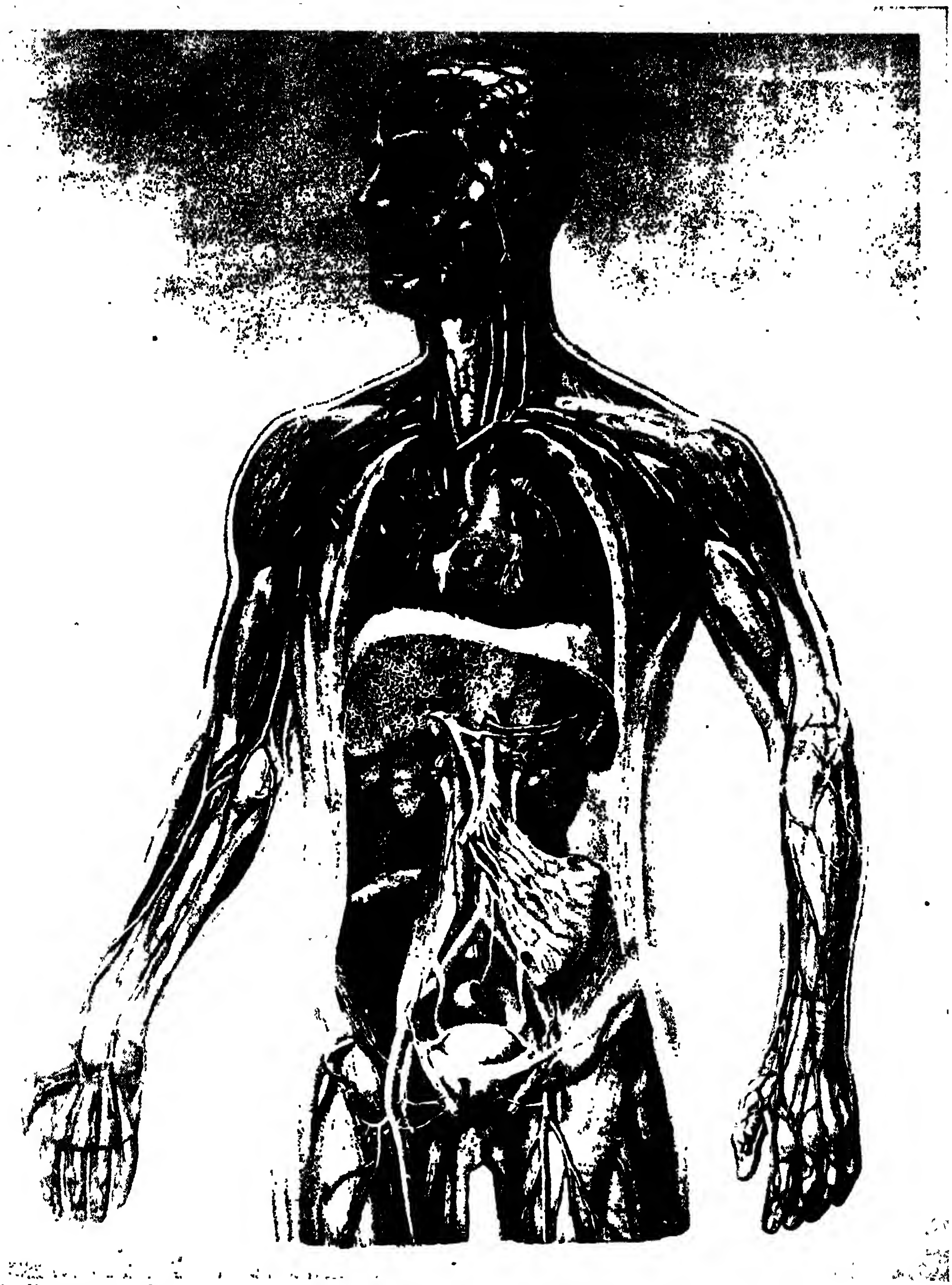


Photo by Clay-Adams Co., Inc.

One page back we saw the general scheme of the circulation of the blood—how it surges through our arteries and veins in two great systems, the pulmonary and the systemic. This picture will help us to see where the main branches of each of these great systems go and how they serve the organs and limbs and other parts of the body. Notice the delicate branching of the pulmonary blood vessels on either side of the heart, where the lungs are. Notice too the enormous aorta and the big vena cava next to it - the body's trunk lines of communication—that go through the central part of the abdomen, serving its vital organs.

in the small space alloted to it in the body.

The heart is hollow. When it contracts, it squeezes the blood onward in spurts, in the way a rubber bulb forces water out when you squeeze it. But a bulb has only one compartment. The heart has four, entirely separate from one another. Two are on top. They are called "auricles" (ô'rĭ-k'l) because they are shaped like ears—and the Latin name for ear is "auris." Since they have only to receive the blood from the large veins entering them, they are thin-walled. Each auricle is separated from the chamber below it by valves that open and shut like swinging doors. The lower compartments are called "ventricles," (vĕn'trĭ-k'l), because they "are round like little bellies"—and the Latin name for "belly" is "venter." They expel the blood. Their muscular walls are much thicker than those of the auricles above. The walls of the left ventricle, especially, are very thick, three times thicker than those of the right. They have to be, for theirs is the most difficult task. The left ventricle pumps the blood through the whole body, while the right ventricle pumps it only to the lungs, to get it "aërated." Since the lungs are not far away, the right ventricle does not have to work so hard or to develop such a strong muscle as the left.

A Queer Fact about the Heart

If you took a rabbit's heart, put it in a jar of salt solution, and added sugar, what do you think it would do? It would keep right on beating. The liquid contains everything it needs: special salts—like those found in the blood—oxygen, and food. Only when these are used up will the heart stop beating. If you put a muscle in the same solution and give it an electric charge, it will contract, too. The heart does not need to be charged. It has its own charging battery to give its messages to the muscle fibers. It does not need orders from the brain to set it working. It is independent. Physiologists have a name for this muscular action that is independent of the brain; they speak of the "myogenic (mī'ô-jĕn'ĭk) theory." "Myo" means "muscle," and "genic" means "beginning." The word thus means that the heart muscle has the power of starting its own beat. The beat starts at the top of the right auricle in a very modified bit of muscle tissue. Then it travels down another band of special muscle tissue the way a snake moves, in ripples. The movement starts in the right auricle and travels down the branches of the special band into both ventricles. This band is called the "neuromuscular bundle of His," because a man called His first discovered it. It is made of nervous muscle tissue. Because impulses like electrical charges pass through it, the ventricles contract after the auricles in perfect time. When this bundle of His is diseased, the impulses cannot travel downward. It is as though a wire were cut. So the auricles beat at one rate and the ventricles at another, instead of working in unison at their task. Doctors then say that the patient has "heart block."

How the Heart Beats

The beat takes place in the twinkling of an eye, as Harvey discovered long ago. It begins with the contraction of the great veins near the heart. Then it is followed immediately by the contraction of both auricles. Then both ventricles contract, for the impulse has reached them through the bundle of His. The ventricles grow shorter. They pull the auricles down. At the same time they get rounder and more like "bellies" than ever. After the ventricles stop working, the whole heart remains at rest for a moment. It has used enough force to pump the blood all over the body.

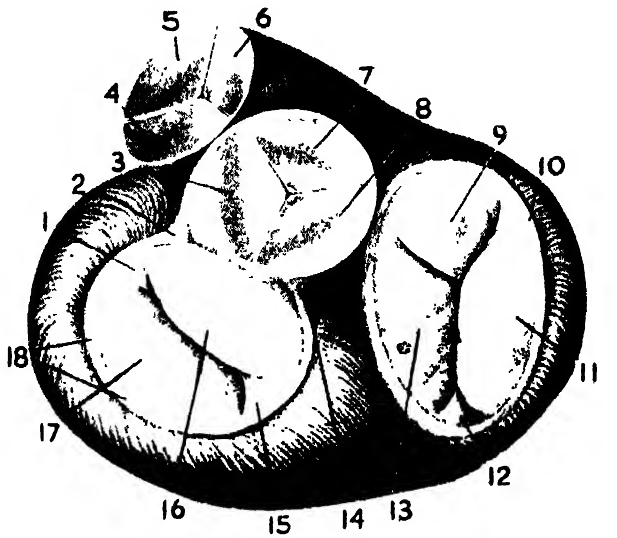
"Listening In" on the Heart

Doctors can tell a great deal about what is happening inside the heart without looking at it through an X-ray machine. All they have to do is to put a stethoscope (stĕth'ô-skōp), an instrument a little like a telephone, to the chest and listen. When the heart goes "lubb," making a long and low-pitched sound, they know that the valves, or swinging doors, between the auricles and the ventricles are closing and that the muscular walls of the ventricles are contracting. If, instead of getting this "lubb," doctors hear a "blowing noise," they know that the valves are not closing properly, that they are diseased. The patient has heart trouble.

The second heart sound is sharp and quick. It goes "dup." It comes from the closing of the doors between the ventricles and the arteries leading from them. There are valves here, too, so that the blood, after it is squeezed out of the heart cannot flow back into it again. If this short, sharp "dup" is replaced by a "murmur," the lower valves are diseased, too.

What happens inside the heart during the "dup," which starts the resting stage, is called the "diastole" (dī-ăs′tô-lē). During the diastole, blood is flowing steadily into the auricles from the great veins, and into the ventricles, too, for the valves are open and hanging down.

Then the "systole" (sĭs′tô-lē), or the beat of the heart, begins. The auricles contract. All the blood is squeezed into the ventricles. The valves between them are pushed upward by the extra blood. They start the "lubb" sound. The ventricles are now closed cavities, for both their top and bottom doors are shut. The ventricles, gorged with blood, receiving their impulses through the bundle of His, immediately contract with a will. The pressure forces the lower doors open. The blood spurts into the arteries, like water squeezed from a bulb into a rubber tube. The ventricles, almost empty, relax. The lower valves close, for the blood in the arteries, pushing against them, forces them to shut. The diastole has begun again.



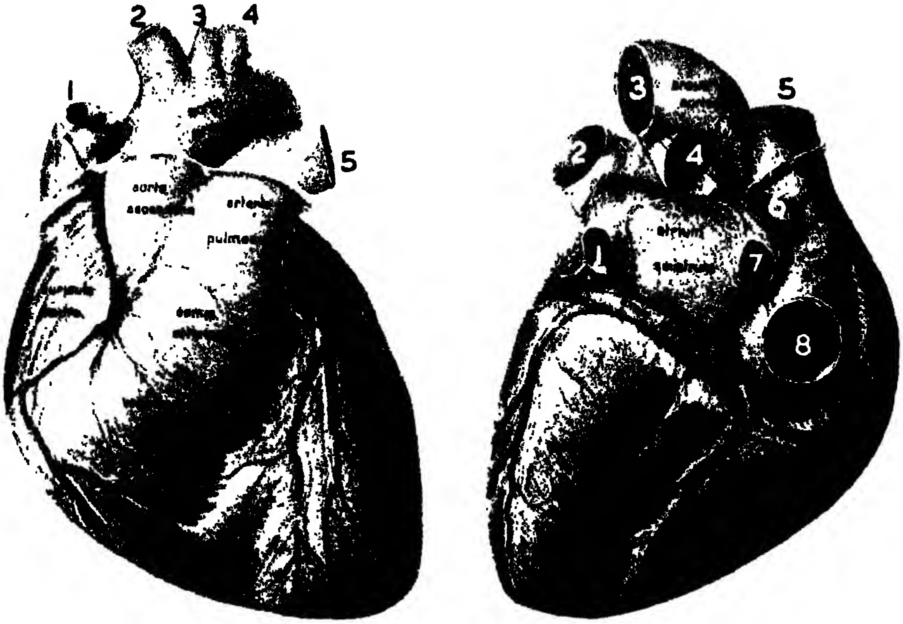
This is the wall between the auricles and the ventricles, seen from above and showing all the main valves of the heart. To get a proper picture of it you should study it in connection with the diagram of the heart in the color picture of the circulation. 4, 5, 6. The three lobes of the pulmonary semilunar, or half-moon, valve, by which the blood leaves the right ventricle for the lungs. 3, 7, 8. The lobes of the aortic semilunar valve, by which the blood leaves the left ventricle for the aorta. 9, 11, 13. Tricuspid, or three-lobed, valve, leading from the right auricle to the right ventricle; 12 is a little "intermediate" lobe between two of the big ones. 16, 17. The mitral or bicuspid—two-lobed—valve, leading from the left auricle to the left ventricle; 1 and 15 are intermediate lobes. 10, 18. Fibrous rings of muscular tissue to which the bicuspid and tricuspid valves are fastened; 14 is the muscular bundle from which the ring of the bicuspid valve starts.

These two, the rest and the beat, make up the heart cycle. It is repeated about forty million times a year as long as we live.

The blood flows on its way in pipes. These are closed, too, and vary in size. The nearer they are to the heart, their power station, the larger they are. The pipe leaving the left ventricle, called the "aorta" (ā-ôr′-tȧ), is the very largest. It sends its branches to all parts of the body. The one next in width is the pulmonary (pŭl′mô-nâ-rĭ) artery, which leaves the right ventricle and goes directly to the lungs.

Now let us follow the blood after it leaves the left ventricle and enters the aorta. The aorta carries the blood a little way, and then gives off little arteries that feed the heart muscles. Soon the aorta branches into other arteries that run upward to the arms and neck and head, and others that go to the wall of the chest, to the vital organs such as the stomach and intestines and all others, and to the legs. These smaller arteries all end in countless little capillaries, which later come together to form the beginnings of the veins. The veins increase in size as they get nearer and nearer to the heart. The largest of them, the two "venae cavae (vē′nē kā′vē), or "hollow veins," pour the blood into the right auricle.

As you know, the blood from the right auricle flows into the right ventricle. From the right ventricle, it is squeezed into the



Here we have two views of the heart; the one at the left shows it as seen from in front; the one at the right, from below and behind. In the left-hand figure, 1 is the end of the upper vena cava; 2, 3, 4, and 5 are the ends of various arteries, 5 being the artery leading to the left lung. In the right-hand figure the numbers stand for veins and arteries as follows: 1, left pulmonary vein; 2, left pulmonary artery; 3, aorta; 4, right pulmonary artery; 5, upper vena cava; 6, 7, right pulmonary vein; 8, lower vena cava. Do not let the scientific Latin names on some of the other parts frighten you; some of them you can translate easily enough without knowing any Latin at all. Thus "ventriculus" is ventricle, "auricula" is auricle, "arteria" is artery, "conus" is cone, and "arcus" is arch. For the rest, "atrium" is used in the right-hand figure to mean a certain part of the auricle; "dexter" means "right" and "sinister" "left"; the "sinus coronarius," or coronary cavity, is the place from which the veins of the heart wall open into the right auricle.

pulmonary artery which carries it to the lungs. In the lungs the pulmonary artery breaks up into tiny capillaries. Here, the blood gives off its carbon dioxide and picks up its new load of oxygen from the air sacs in the lungs. It is now a brilliant scarlet—"blood red." After this exchange, the aërated blood collects into larger and larger veins. At last, it reaches the pulmonary vein, which transports it to the left auricle. When the heart contracts, this bright red blood is pushed from the left auricle into the left ventricle, and out into the aorta again. So we are back where we started. And the whole journey takes less time than you take in reading about it. Only forty seconds at the most!

The blood thus flows round and round, in two circles. The bigger one, which takes the blood from the left ventricle all the way around the body and back to the right auricle, is called the "systemic (sĭs-tĕm'ĭk) circulation." The smaller one, from the right ventricle to the lungs and back to the left auricle, is the "pulmonary circulation."

The Portal Circulation

There is still another circle inside the systemic, a kind of detour. It is called the "portal circulation." The arteries going to the intestines break up into capillaries. Here, the blood picks up food stuffs, the body's fuel supply. These food stuffs are not taken to the heart immediately. They are transported to the liver by the portal vein. In the liver, which is the body's reservoir for glycogen (glī'kô-jĕn), or animal starch, the portal vein breaks up into capil-

laries. For it is only in the capillaries, the tiniest channels possible, which come to their very doors, that our engines, the cells, give off their by-products and wastes and take up their supplies. When that is done in the liver, the capillaries again form veins, the hepatic (hē-păt'ĭk) veins, which join a still larger vein going to the heart. The portal circulation, you see, is a venous (vē'nŭs), or vein, system that starts the distribution of the food stuffs through the body.

The amount of work the heart does is extraordinary. It is about enough in one day to lift an ordinary man nearly half a mile into the air. All this force is needed to keep the blood flowing through its channels.

Now those channels, or blood vessels, are not stiff like lead water pipes. They are more like rubber tubing. The arteries especially are like that, for they are thick-walled pipes made of muscular and elastic tissue. Like the heart, they have three layers. The outer coat is made of fibrous tissue. The middle coat is made of muscle, but of a different kind, not striped like the heart or skeletal muscle. It is made of the unstriped or involuntary tissue. Among the muscle fibers, which are arranged in circles, there are also many yellow elastic fibers. That makes the middle layer of the arteries very strong and elastic, too. The inner layer, like that of the heart, is very, very smooth, to make as little friction as possible when the blood flows through.

This is a section of the heart from behind, showing the auricles and the right ventricle; the wall of the left ventricle has not been cut away. 1. Tendons of the bicuspid valve. 2. Left pulmonary vein. 3. Left auricle. 4. Wall between left and right auricles. 5. Pulmonary vein. 6. Muscular wall tissue. 7. Oval space, without muscle. 8, 9. Muscles. 10. Right auricle. 11. Right coronary artery, which nourishes the heart itself. 12. Tricuspid valve. 13. Right ventricle; note the long, strong muscles in it.

Places without a Blood Supply

You remember what the capillaries are like, and how they form a dense network round and among the tissues in almost every part of the body. But there are some parts that have no blood vessels. The hair and nails have none, and cartilage or gristle has none. That is why it is so white.

The capillaries are made of a single layer of very thin cells, and they are so small that the red blood corpuscles have to squeeze through them in single file.

But the thick-walled arteries do not turn at once into thin capillaries. They gradually break up, or divide, into narrower and thinner tubes. These tubes, called "arterioles" (är-tē'rĭ-ōl), meaning "little arteries," get even smaller till they form the capillaries at last.

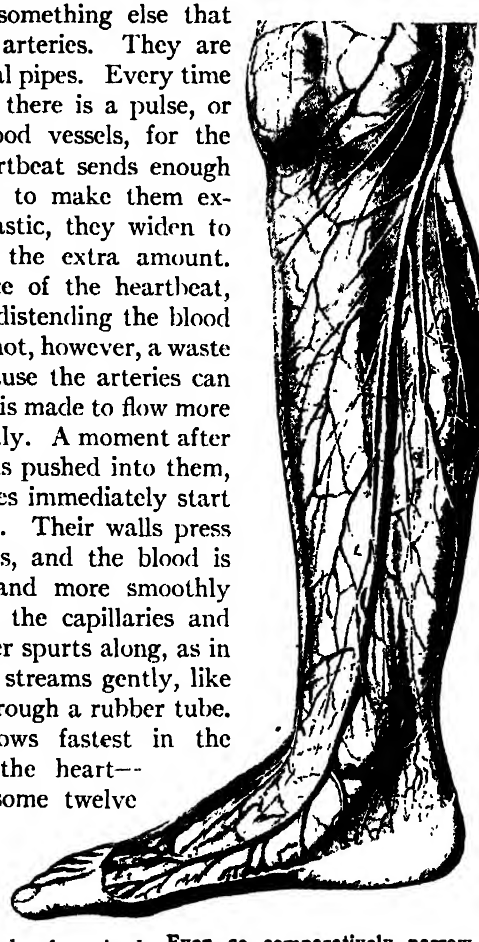
In the same way, the capillaries do not join into veins immediately. They form "venioles" (vē'nĭ-ōl) first, or "little veins," corresponding to the arterioles. These get bigger and bigger till they form the veins. The veins are not so thick-walled as the arteries, however. They are made of three coats, too, but they have not so much muscular or elastic tissue in their middle coat. They are strengthened, however, by a great amount of fibrous tissue in their outer coat. Besides, the veins have an extra contrivance. They have valves inside the inner layer, like the breast pockets inside your jacket. These valves keep the blood from flowing backward.

The blood flows from the heart into the capillaries exactly the way water speeds through pipes to your house from its pumping station. The force or pressure of the blood is greatest in the arteries nearest the heart because these are nearest the station, just as the water pressure is greatest in the pipes nearest the pumps. With every beat the blood leaps onward, as anyone will see if he is unlucky enough to cut an artery. But as the blood flows along, its force is

spent in overcoming the friction against the walls of the blood vessels; for no matter how smooth they are, there will be some friction against their walls. In your town water system, there is the same kind of friction in the lead pipes, and it uses up the water pressure. Friction is only a name for rubbing.

But there is something else that happens in our arteries. They are not stiff like metal pipes. Every time the heart beats, there is a pulse, or beat, in the blood vessels, for the force of the heartbeat sends enough blood into them to make them expand. Being elastic, they widen to make room for the extra amount. Part of the force of the heartbeat, then, is used in distending the blood vessels. This is not, however, a waste of energy. Because the arteries can widen, the blood is made to flow more and more smoothly. A moment after the extra blood is pushed into them, the elastic arteries immediately start into shape again. Their walls press on their contents, and the blood is squeezed more and more smoothly on. At last, in the capillaries and veins, it no longer spurts along, as in the arteries, but streams gently, like water flowing through a rubber tube.

The blood flows fastest in the arteries nearest the heart—at the rate of some twelve inches a second. In the capillaries it merely creeps—perhaps as fast as a fiftieth of an inch a second. As it comes back through the veins it goes faster and faster in approaching the heart. In the jugular vein, in the neck, it is going over five inches a second.



Even so comparatively narrow a part of the body as the leg has to have three distinct layers of veins, arteries, and nerves to serve it. This picture shows the top, or "superficial," layer of veins and nerves in the lower leg.

But if the whole stream has to keep going constantly, how can it slow up at any point? If it starts very fast and then gets very slow, why does it not "back up" somewhere? And then if it plunges ahead again, why does it not leave an empty space behind? Well, that is very prettily arranged. When a big artery splits up into several smaller ones, the size of all of these together is always a good deal larger than that of the one big artery. They hold more blood, and the blood may therefore travel more slowly, without "backing up." These then split up into still smaller arteries, with still greater capacity, and the blood can go still more slowly. Finally it reaches the capillaries, and tiny as each of these is, they are so numerous that together they hold far more blood than the first artery. So the blood can now go very slowly indeed. The same thing is true, in reverse order, back through the veins. That is why the blood can go far faster near the heart than in the capillaries. In the capillaries it can therefore take plenty of time to do its work of giving out supplies and taking up wastes.

Every time the heart beats, there is a pulse, or beat, in the arteries that anyone can feel. You know how the air blown into a rubber glove will expand the fingers. The blood does the same thing in the blood vessels. They are elastic, and the extra blood poured into them widens them. The pulse starts in the aorta. It travels through the blood vessels, expanding their walls as it goes, like a wave moving farther and farther on, till it reaches the remotest ends.

You can prove this for yourself by "taking your pulse" and at the same time feeling your heartbeat. If you place your right hand over your heart and the thumb of your left hand on the wrist of your right one, you will see that the number of beats at both spots is the same. But the beat at the heart always comes a little sooner than the beat at the wrist. If you cross your legs at the same time in such a way as to let the hard bone of the bottom knee press on the great artery running down the back part

of the top knee, you will see a jerk of your foot every time there is a pulse beat. When does this one come? A little later than the pulse at the wrist, does it not?

The heart pump has enough force to drive the blood all through the body. It is helped, however, by our breathing and our movements. For every muscular movement, pressing on the veins, squeezes the blood along toward the heart.

How Much Blood Have You?

When you race or jump or play basket ball, your heart beats much faster and harder than it does when you loll in a hammock. In fact, the amount of blood it sends out per minute during exercise is two or three times as great as during rest. For there is only a certain amount of blood in the body, about one-twentieth our weight. That makes seven and a half pounds for a hundred-and-fifty-pound man. When the heart beats harder and faster, the blood streams round and round in its double circle faster and in greater quantities. More blood enters the heart than usual. Why? Because we breathe more deeply and quickly. Our contracting muscles, too, squeeze the veins lying among them and force great streams of blood to the heart.

But if too much blood should reach the heart at once, the organ might burst. The pericardium never allows that. The fibrous sac lets the heart be stretched just so far and no farther. The pressure in the right auricle becomes so great that it keeps the fast-flowing blood from entering the heart at once. Instead, it remains in the capillaries of the lungs and in the veins coming from them. These widen or dilate tremendously. They act as an extra reservoir to hold the overflow till it is needed.

The Cause of a Heavy Heartbeat

The great amount of blood entering it at one time makes the heart beat harder. For when muscle fibers are stretched, they contract with more force than usual. The heart is a hollow muscle. The extra blood fills it to overflowing, presses on its muscle fibers, and stretches them just as water stretches a rubber balloon. The fibers contract with all their might, press on the blood in their turn, and squeeze it out to flow to the furthest corners of the body. The heart, pumping as hard as it can, thumps against the wall of the chest so hard that you feel it easily.

A while ago we said that a little way from the left ventricle, the aorta gives off some branches, called the coronary (kŏr′ō-nȧ-rĭ) arteries, which supply the heart muscle itself. The blood that flows into these vessels has more to do with the force of the heartbeat than you might expect. More blood flows through them when we exercise, because it is flowing faster and in greater quantities. So the blood carries large supplies to the fibers of the heart muscle. It gives them more oxygen and food, and a great deal of calcium and potassium salts. Large amounts of these things make the fibers work harder, and the heart contracts with great force.

Speeding Up the Heartbeat

The wider the coronary arteries are opened, the more of these substances reach the heart. Carbon dioxide will dilate the arteries. A special substance called adrenalin (ăd-rĕn′ȧ-lĭn) can dilate them, too. Adrenalin is a hormone (hôr′mōn)—one of those substances that have the task of exciting tissues to work. It makes the muscle fibers of the coronary vessels relax, and so widens them.

These substances flowing through the blood vessels do not make the heart increase its speed. Only when the blood gets very hot does it make the heart beat faster. That is why the heart races during a fever, when the blood is greatly heated. But there are still other things that make the heart go faster.

In our story about breathing we told of the sensitive center—in that part of the brain that never sleeps—which takes care of our breathing movements. There are two similar sensitive centers for the heart, and they also never sleep. One of them makes the heart beat more slowly. It keeps the "brakes" on, and inhibits, or checks, the heart's action. It is called the "inhibitory (ĭn-hĭb′ĭ-tō-rĭ) center." The other does just the opposite. It speeds up the heart, making it beat faster and faster. Therefore it is

called the "accelerator (ăk-sĕl'ĕr-ā'tĕr) center." Both of these centers send out nerves over which their messages travel to the heart. So, since the centers never sleep, there is a constant flow of orders to the heart. Some tell it to hurry, others to stop speeding. These messages balance each other, and the heart beats at a rate midway between that called for by the two alert centrals.

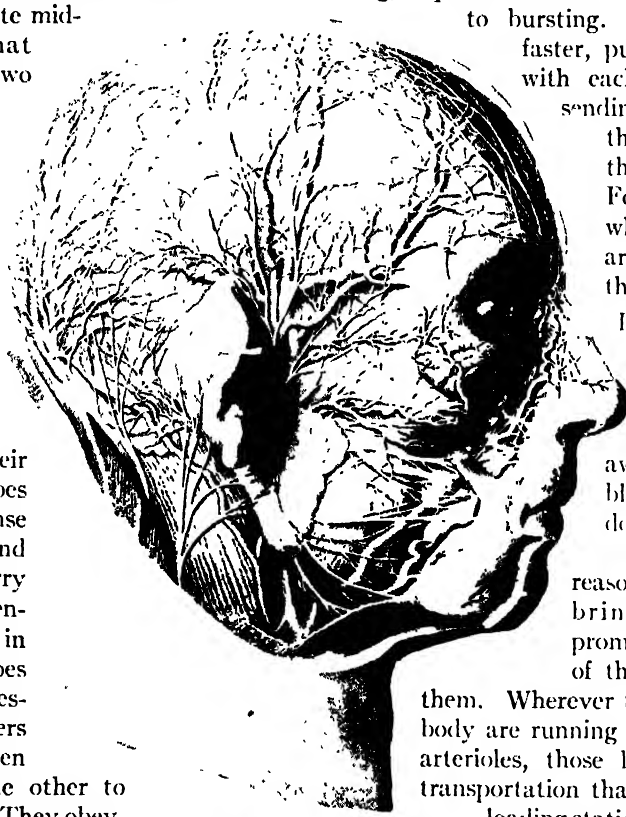
The centers are sensitive. They get messages from different parts of the body and relay them to the heart, telling it to beat fast or slowly. The lungs, for instance, send their dispatches. So does the aorta. The sense nerves in the skin and elsewhere also carry messages to the centers. When we are in pain, our heart goes pit-a-pat, for the messages to the centers tell the one to loosen the brakes and the other to work even harder. They obey, and the heartbeat quickens.

The higher brain—the part that thinks and feels—also sends messages to the centers. When you are excited or angry, your heart races away. You feel ready to try anything, to dare all.

How the Heart Prepares for a Race

Suppose you are getting ready to run a race. On your mark, get set! Is your heart beating faster and your breath coming quicker than before? That is because the higher brain has already sent its messages to the centers, releasing one from its work and ordering the other to work harder. Your blood flows faster. More supplies reach your muscle fibers, and they are ready to work as hard as they can. If you do not win the race, it is not because your body is not all for you.

Why is this quickening of the heart so important during exercise or work? For one thing, it prevents the heart from being filled to bursting. The heart beats faster, pumping less blood with each beat, but still sending far more through the body, owing to the livelier speed. For another thing, when your muscles are working hard they need more supplies from the blood, and they give off more waste products to be washed away by it. So the blood has to race to do its work.



These many-branched and interlacing trees are the outer layer of arteries, veins, and nerves in the head. This will barely give us an idea of how many of them there are, for other layers are beneath.

There is a special reason why the blood brings supplies so promptly to the parts of the body that need them. Wherever the engines of the body are running at full speed, the arterioles, those little channels of transportation that lead to the unloading stations of the factories or organs, open their floodgates, or widen, to let the blood rush through to the capillaries. The blood vessels have stopcocks, which, regulating the bore, or width, of the vessels, allow the blood to flow to those factories that send in orders for more raw materials.

At the same time that Pasteur was showing the world that microbes are a menace, Claude Bernard, dean of French scientists, was quietly finding out about the stopcock regulator and how it works. He discovered that when he cut a certain nerve in the ear of a white rabbit, the ear became red. Vessels that had been empty before widened, because they were gorged with blood. When

Bernard stimulated this nerve by an electric shock, the ear grew pale. In this way he proved that there are nerves running to all the arterioles in the body—except to those of the heart and the brain—constantly carrying messages from the brain center to the arterioles to keep the arterioles in a state of tone—neither too tightly shut nor too widely open. When the brain center increases its telegraphic speed, it makes the arterioles grow smaller. When it stops sending so many messages, the walls of the blood vessels relax and more blood flows into them. It is called the vasomotor (văs'ō-mō'tẽr) center, because through its nerve it directs the action of the muscle walls in the blood vessels.

Claude Bernard was a brilliant man. He discovered something else. He found that there is another set of nerves that do nothing but widen, or dilate, the arterioles. These are the "vasodilators" that run only to certain parts of the body, such as the salivary glands, the tongue, and the cheeks. These vasodilators do not work all the time, as do the others, called the "vasoconstrictors." Only when certain organs need more blood do they carry messages to widen the channels leading to the factories.

Stopcocks That Control the Blood Flow

Suppose you are running the race we mentioned. What happens to the circulation? The heart beats faster and harder, and your breath quickens even before you start to sprint. Your blood pressure also rises. That is because the vasomotor center is very sensitive. Getting messages during the "Get ready, get set" from the higher brain, it immediately sets to working harder. It relays its messages thick and fast to the arterioles all over the body. They get narrower and the blood pressure rises. For the blood has a hard time streaming through the arterioles, and so it pushes with more force, flows faster, and reaches the muscles in record time. The capillaries in the muscles, most of which have been closed and empty during rest, are now gorged with blood. In fact, the stream-bed area of the capillaries may increase about fifty times!

Since there is only a certain amount of blood in the body, something else happens that makes the stopcocks very necessary. If there is so much blood in the muscles, there must be less of it somewhere else in the body. The blood vessels in the region of the stomach and intestines are shut by the vasoconstrictors. They get so small that the blood cannot flow into them easily. Instead, it is diverted from them and switched into the wide-open vessels. So the blood flows to the muscles, where it is most needed, and they are flooded with it.

Why We Get Hot and Red

That is what happens at the very start of the race. After you have been running for a while, you get hot and red. The blood from the viscera (vĭs'ẽr-ȧ)—the stomach and intestines—has been switched into the vessels of the skin, too.

Your muscles have been working for all they are worth. Their waste products, carbon dioxide and lactic acid, have increased tremendously, and have been discarded into the blood stream. Here, these substances act on the walls of the vessels. The vessels widen, and more blood rushes in to fill them.

Besides, the vasomotor center is very sensitive to the blood streaming through it. It feels the slightest increase of lactic acid and carbon dioxide. Then it works harder than ever, and closes the visceral vessels tighter than before, thus raising the blood pressure and sending more blood to the muscles.

Why Eating Makes Us Sleepy

When you are eating, where does the blood go? To the visceral area, because it is needed there to help in the work of digesting your food. The arterioles open their floodgates to let the blood rush through to the wide-open capillaries. And what part of the body loses its blood to the stomach? The brain loses a great deal. And that is why we get sleepy after we have eaten a big meal. Most of the blood has been taken away from the brain, which cannot work well, or think well. It is drowsy, you begin to nod.

If you exercise right after a meal, you start a civil war in the body. The blood that ought to flow to the digestive organs is called

Of the nine branches of the aorta, the second largest is the upper, or superior, mesenteric, shown here. The folds of the small intestine are drawn forward to show how the branches of this artery are distributed.

to the muscles instead. Digestion is disturbed.

It is easy to see that the vasomotor center is very important. When it does not work properly, there are still further disturbances in the body. This is all the more true because we stand upright, instead of on all fours like other animals, and as a result our blood system has to work against gravity to send blood to the brain. For instance, if we have been lying down and suddenly stand up, the blood, owing to the force of gravity, tends

This unfortunate youngster, late for school, finds himself growing hot all over. How glad he would be if only those two little centers in his brain had kept on working normally!

to remain in the abdomen. The supply to the brain is lessened. The vasomotor center feels the change immediately and sets everything right by closing the stopcocks in the abdomen in order to give more blood to the brain. So sensitive is the center to any change of position in the body, and so perfect is its control of the blood vessels, that we never feel it working. But if anything goes wrong, there is a different story to tell. Then a sudden change from lying down to standing up may make us dizzy. If things are still worse, we may faint. The blood pressure is too low for enough blood to reach the brain.

Why We Blush and Turn Pale

When the skin is hot it flushes, and when it is cold it turns pale. The little sense spots of hot and cold in the skin send different messages to the vasomotor center. The cold spots, feeling anything cold, relay the fact up to the center. It works harder. The vessels are constricted, and grow smaller. The blood is squeezed out of them. The skin grows pale. When the skin is hot, the message that is relayed to the same center makes it stop working so hard. Then the vessels dilate, and blood rushes in to fill them. The skin flushes.

Messages of pain from the skin make the center work harder, and the skin becomes pale.

Our feelings also affect the blood supply to the skin. Embarrassment or shame flushes the skin with blood. The vasomotor center, which constricts, or shuts, the blood vessels, is told by the centers of feeling to stop working at top speed. It does. Our feelings are relayed up to the vasodilator center as well. It starts work and sends messages to the cheeks. Their vessels dilate, and we blush—much faster than we take to tell it.

When a person blushes to the roots of his hair, both the vasomotor and the vasodilator centers are responsible. The vasodilator, working hard, widens the vessels of the cheeks. The vasomotor, not working so hard as usual, allows the blood vessels in the rest of the face to relax and become flooded with blood.

Reading Unit No. 15

HOW DOES YOUR BRAIN WORK?

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

How the false "science" of phrenology began and ended, 2–383-84
How we came to learn the function of each part of the brain, 2-385
Functions of the brain stem and cerebellum, 2–385-86
The cerebrum, most important part of the brain, 2–386-89
How scientists learn what the cerebrum does, 2-387-89
How we are able to think, 2-390

Things to Think About

Why do we no longer respect the "science" of phrenology?
What would happen to a person if the lower part of the brain stem were cut across with a knife?
In what way are the brains of geniuses and idiots different?
How did Dr. Hitzig discover so many facts about the cerebral cortex?
How do we get information about the function of different brain centers?

Picture Hunt

Where is memory and thinking located in your body? 2-383
What are the parts of our central nervous system? 2-384-85
What part of the brain has wrinkles on its surface? 2–390
Where is the pituitary gland found? 2–385
What is still unknown about the cerebellum? 2-386

Related Material

In what protective tissue is the brain inclosed? Color plate opposite 2–278
How are messages from the brain sent to the finger tips? 2–393
What are some reflex acts? 2–393-94
How is a reflex act made possible? 2-395

Leisure-time Activities

PROJECT NO. 1: Obtain a calf's brain from the butcher. See how many parts you can identify. See pictures on 2–384-85, 387.

Summary Statement

The brain sets us apart from lower animals because it enables us to think and to reason. The lowest part of the brain, the medulla, automatically takes care of the digestive tract and controls the heart-beats and our breathing. Injury to this part often results in death. The cerebellum coordinates our muscles so that we can work or play.

How does he know the coming jerk is going to hurt? Because his brain warns him, from previous experience.

And why is he going to pull anyway? Because his brain knows he will be the better for it in the end.

Photo by H. Armstrong Roberts

HOW DOES YOUR BRAIN WORK?

Do You Know That It Has Various "Departments" Leading up to the Office of the "Master Mind" Which Does Your Thinking?

IN THE year 1807, when the great Napoleon was at the height of his power, a German doctor named Franz Joseph Gall packed his bags and set out for Paris, the center of the intellectual world. He had a new science that he wanted to teach.

Ever since he had been a young man, Gall had studied the shapes of human heads. He studied those of his friends. He visited prisons and insane asylums and associated with low companions only to study their heads. He noticed that different sorts of people had different kinds of bumps on their skulls.

"Now," he said, "most of the brain cavity is filled by the cerebrum (sĕr'ē-brŭm), an outgrowth of the forebrain. It has its gray matter on the outside, while its white matter is on the inside. I have already dissected out some of the white fibers. They connect the different centers of the gray matter, or cortex. Each of these areas must be the seat of a different feeling or sentiment. The skull is nothing but a box. At every place where there is a bump on it outside, at that spot the brain inside is more developed than elswhere."

Thus Gall had the idea that different regions of the gray matter of the brain are

in charge of different departments of our mental life. He said that the cortex was really made up of a number of separate organs, and he mapped out the seat of each sentiment in a definite area of the brain. He thought that the base of the brain, at the nape of the neck, was the seat of the sentiment of love. "Combativeness" he placed behind the ears, because he noticed that some of the more quarrelsome of his low companions had big bumps there. He even found such bumps behind the ears of a quarrelsome young lady! Thus he continued to locate the sentiments of the brain by the corresponding bumps on the skull till he had numbered thirty-five of them. The bump at the top of the head stood for "veneration," because Gall noticed that the people who prayed with the greatest fervor in church had the biggest bumps there. "Tunefulness" was placed on the temple, because Gall found a bump at that point on the head of a boy who showed musical genius.

In Paris, Gall made many converts to his new science. It was called phrenology (frĕ-nŏl′ô-jĭ). People all over France and England and America were soon busy studying one another's bumps to see what their characters and dispositions were like. But the new science also made many enemies, who scoffed at the idea that bumps on the head mean anything about what goes on inside it.

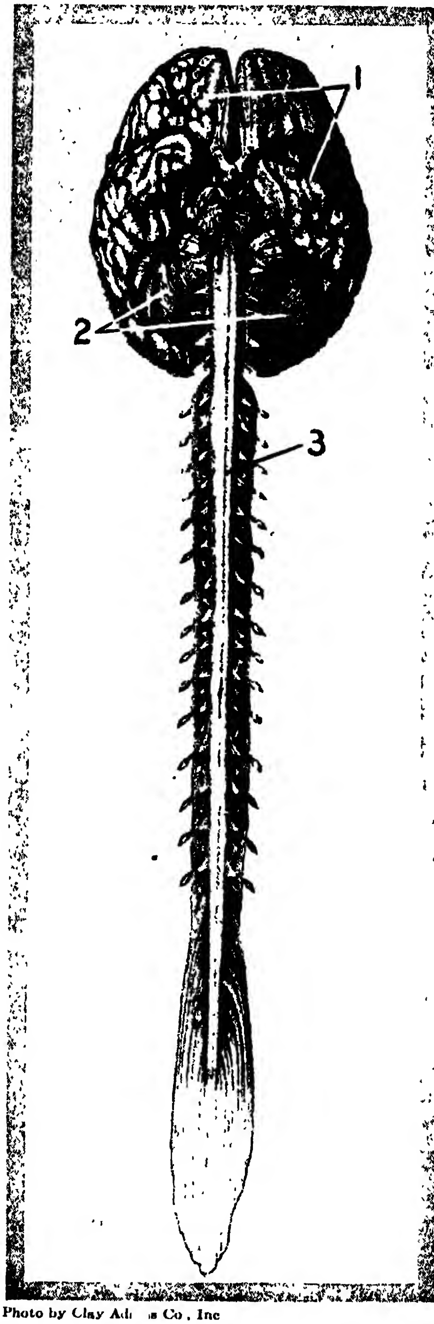


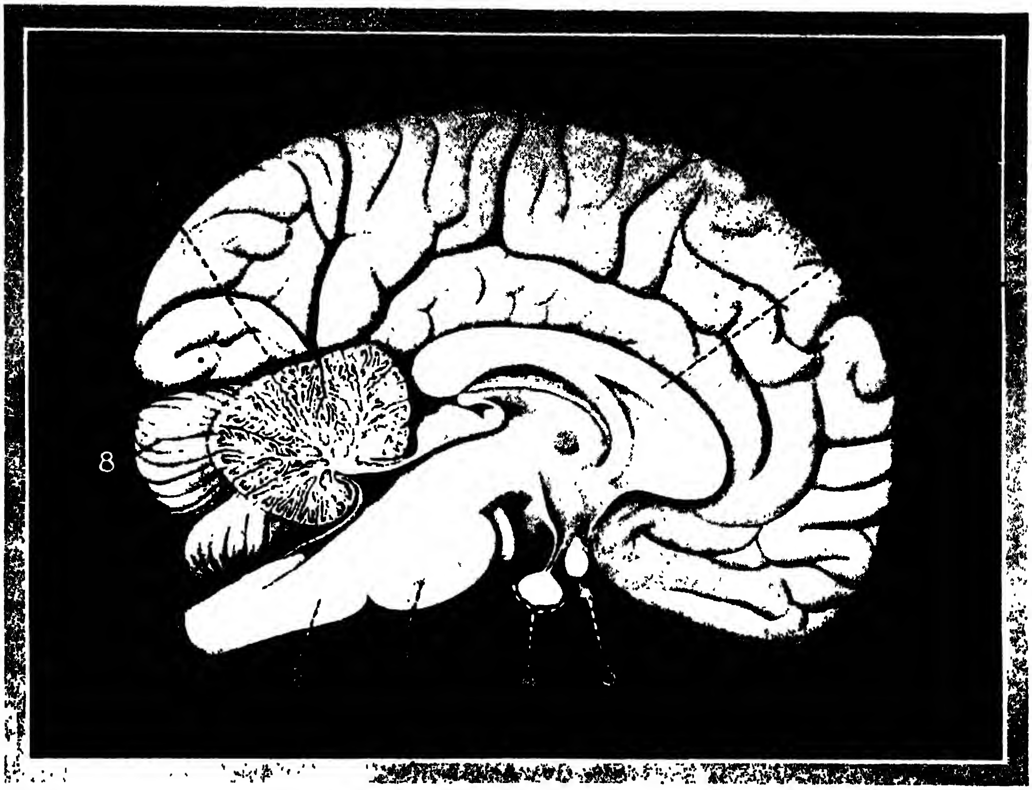
Photo by Clay Ad... Co, Inc

This is the general appearance of our central nervous system from in front. 1. Cerebral hemispheres, the "central offices" of the system. 2. Cerebellum, chief center of reflex action. 3. Spinal cord, which runs down inside the backbone. The little points and knobs are cut nerve ends.

The French scientist Flourens (flōō′răNs′) disputed Gall's theories. He said that the cerebrum was one single organ whose parts all did the same work. He showed by experiments on pigeons that when a certain part of the cortex was removed there was no change in the animal's actions. Only when too much brain was removed did the pigeon lose all of its nervous characteristics; and then it lost them all at once.

Most of the scientists sided with Flourens, for the weight of evidence was with him. There was one discovery that told against him, but it was not fully understood. In 1860 a French physician named Broca discovered that when the front part of the cerebrum was injured on the left side, a person could no longer speak distinctly.

Gall had the beginning of a good theory, though the application of his ideas was wrong. He and his disciples contributed a great deal to our knowledge of the finer structure of the brain, but his "science" of phrenology was taken out of the hands of scientists and adopted by all sorts of persons who found they could make a living out of it. There are still some of these left in the world.



Here is a picture of the brain stem and the brain cut down through the middle to show as many as possible of the parts. 1. End of spinal column. 2. Medulla oblongata. 3. Pons, or "bridge." 4. Pituitary gland. 5. Optic nerve. 6. Corpus callosum, a body of fibers between the two hemispheres ot the cerebrum. 7, 8. Cerebellum. The part marked 7 has been cut across; that marked 8 shows the outer surface. The great wrinkled half circle on top is one of the cerebral hemispheres, seen from the inner surface.

The beginning of our real knowledge of where the functions reside in the cortex of the brain came with the discoveries of a German physician named Fritsch. During the Franco-Prussian War of 1870, Fritsch was operating on the head of a wounded soldier. Accidentally he passed an electric current through his patient's brain. At once some of the soldier's muscles began to twitch. With that twitching, a new field in the science of physiology was opened up. For when Fritsch went home from the war, he worked with his colleague, Dr. Hitzig (hĭt'-sĭK) to find out all that the twitching of the wounded soldier meant.

A little later we shall tell you what he found. But we must first study the brain a little in order to understand his discovery.

If your eye could travel up the central canal of the spinal cord to the brain at the top, what would it find there? It would come to the "brain stem." It would notice that the canal has widened out, and that a high wall has risen. This upright wall is so thin that you can hear the drumming of the blood vessels that feed the brain on its other side. Soon the wall thickens again, and you reach an even wider part of the cavity. Behind you lies the great cerebellum (sĕr'ĕ-bĕl'ŭm), the first large outgrowth of the brain stem. Beside you and in front, you can see a set of slight bulges on the wall. These are important in many reflex actions.

Busy "Central Stations" in the Brain

For this lowest part of the brain stem is one of the busiest sections of the brain. It has many "centrals" all operating at the same time. One of them takes care of the movements of the muscles in the digestive

Above at the left is the cerebellum as seen from above, at the right as seen from below. Scientists are still experimenting to discover which part of the cerebellum controls head, neck, limbs, and trunk.

tract. Another controls the flow of the saliva and of the juices of the stomach and pancreas (păng′krē-ăs). A third controls the breathing movements, while a fourth takes care of the heartbeat. Still another center sees to it that the size of the blood vessels is changed to suit the needs of the body, while another is in charge of the movements of the face and throat. Nor is that all. Eight of the twelve nerves running to the head end in this lower part of the brain stem. And there are great bundles of nerve fibers that come up from the spinal cord and pass through this part of the "hind-brain" to go on to the higher brain above.

What Is the "Little Brain"?

About that higher brain we are going to speak in a moment. Let us first pause a while to say a word about the work of the cerebellum—which means the "little brain."

Perhaps you have been carelessly walking along on some sunny day and have suddenly found that you were about to fall down a steep incline. But before you knew it you were pulled back. It was the cerebellum that did that. For through those great bundles of fibers the cerebellum gets rapid messages from the sense organs in the inner ear; these tell it of the changes in the position of the head. It also gets messages from the end organs in the muscles and tendons. Since this "little brain" is an automatic central, it is busy all the time sending messages out. The messages are sent in response to the ones it receives. Through its great bundles of fibers it sends messages to the muscles to keep them in a state of tone, ready to act. Its chief work, however, is to see that the body is kept in an upright position in spite of gravity, and that the muscles all act together when they work. This is no small task. The cerebellum does it by sending endlessly message after message to the muscles.

Now you may leave the hind-brain, the busiest part of the brain stem, and go on to the mid-brain. Here you notice a set of swellings which are the optic lobes. The mid-brain contains two important cell stations or centers. One is for hearing, the other for seeing.

You have reached the end of the brain stem, but you continue to travel further. After seeing various things, you finally come to the cerebrum, or the cerebral (sĕr′ē-brăl) hemispheres—the forebrain. Here is where the "master mind" lives. Here is the office of the main operator in the whole system.

The Most Important Part of the Brain

In man, these cerebral hemispheres are the most important part of the brain. They are the biggest, too, and cover up most of the other structures we have just explored. In shape, both cerebral hemispheres are like a half melon that has been sliced again down the center from front to back. They are very much wrinkled and deeply grooved, so that the whole surface is thrown into

folds. This is a very fortunate thing for us. For these folds, grooves, and wrinkles increase the surface area of the cerebrum very greatly, while still allowing it to fit comfortably into its box in the skull.

In the cerebrum, it is the surface, or "cortex," that is important. Like the outside of the cerebellum, the cortex is gray—that is why we talk about a person's "gray matter"; and it contains three layers of nerve cell bodies and their fibers. The two bottom layers form the "old mantle" of the cortex, for they were the first to appear in the lower animals. The top layer forms the "new mantle," which reaches its highest development in the human brain. The scientists think that in man each of these three layers has different tasks to perform. The lowest layer of the cortex takes care of the things we do by instinct to get food and to protect ourselves from danger. These are the things that mainly keep the animals busy. The middle cell layer is a receiving station. It receives and transforms the S.O.S. messages sent up to the brain from all the sense organs in the body. The outer cell layer, or new mantle, is the real master mind. It takes care of our thinking, our willing, and our remembering. The thicker this outer layer of the cortex, the better the "brains" of a person. Idiots and imbeciles have very little of this new mantle in their cortex, while demented people show decay in the cells of this outer layer.

Here is a diagram of a section through skull and brain, showing the three layers of brain covering where they curve down between the two cerebral hemispheres. 1. Bone of the skull. 2. Strong outer layer called "dura mater," or "hard mother." 3. Middle layer, called "arachnoid"; this word means "like a spider," and refers to the delicate, cobwebby texture of the membrane. 4. Inner layer called "pia mater," or "kind mother." 5, 10. Specialized outgrowths of the arachnoid. 6. Space under the arachnoid, filled with fluid. 7. Part of the corpus callosum. 8. White matter of brain. 9. Gray matter. 11. Veins.

How do we know that the cortex is the master mind of the body, the chief operator that controls all other centrals? We have found it out by experimenting on animals, as Flourens did. A frog or a pigeon still lives when its cortex has been removed, but it no longer acts like a natural frog or pigeon. It can move, but it does not do so. It does not know enough even to go looking for food, for it has no memory and no longer knows what food means. It simply lies still, ready to die of starvation. A dog without a cortex would move about, but he would no longer know his master. He would never wag his tail when petted, nor would he put it between his legs when scolded. In fact, he would not act in the least like the household pet we know, the best friend of man among the lower animals.

There was once a child born without a cerebrum, and his case gave us still further evidence that the cortex is the master tissue of the body. He lived for four years, and though he grew in size, he remained as complete a baby as on the day he was born. He never showed the least sign of intelligence. He could not recognize his mother. Most of the time he lay half asleep. He never learned to do anything except to eat the food that was put into his mouth, and to cry.

How We Remember

So the work of the cerebral hemispheres is that of chief executive. It combines the effects of every new message or stimulus from the nerves with the messages or stimuli of the past, and then acts by sending messages out based on these combinations. All these messages or stimuli leave a permanent record in the cells of the cortex. This permanent record is our memory; and that memory, combined with the new stimulus, helps the master mind to decide how it shall

act. "A burnt child dreads the fire" simply because the permanent record in the cells of its cortex warns it to keep away from this danger.

Now let us go back to Fritsch, of whom we were talking a moment ago.

In 1870, you remember, Fritsch came home from the war. He was very much excited, for he had a clue that led he knew not where. All he knew was that an electric current passed into the brain starts some of the muscles twitching. Why? With his friend Hitzig he set to work to find out. They took some dogs, and operated on them in such a way that part of the cerebrum was revealed. Then they proceeded to pass electric currents into various parts of the organ.

They found out that if they stimulated one point of the cortex of the right hemisphere, the muscles of the left foreleg would twitch. If they stimulated another point, the muscles of the opposite hindleg would wriggle. Another spot, they found, was the center for the muscles of the neck, another for the face. Over and over again, Fritsch and Hitzig passed the electric current into a dog's brain, and every time they touched the same spot the same muscles would twitch. At last they knew these spots so well that they could make a map of them.

Photo by the National Museum

Dr. Walter Reed was the chairman of the commission that the United States government sent to Cuba in 1900 to investigate yellow fever. He and some twenty others allowed themselves to be bitten by mosquitoes who had bitten patients suffering from the disease. They heroically established the fact that yellow fever is spread by the bite of infected mosquitoes.

"Old Gall had the right idea," they said. "Definite parts of the cortex have definite tasks given to them."

They wrote out their findings for a scientific magazine, so that the whole world might know what they had proved.

This helped other scientists to go on with the same work. In the end they mapped out all the muscle, or "motor," centers in the brain. In a diagram of their findings you could see that the whole motor area is found in front of what is called the fissure, or cleft, of Rolando. The brain cells that control the toes of your left foot are found at the same level in the left hemisphere. Below are the centers for the muscles of your ankles. Then come those for the knee, hip, and so on, until those lowest down control the muscles of your face.

These centers are not merely automatic, like those in the spinal cord and the brain stem. They are the centers of your voluntary movements, under the control of the chief operator. They work when you will it; that is, when they get messages from other parts of the cortex, or from the automatic centrals in the spinal cord and brain stem.

"But how is it," you may ask, "that the left side of my brain controls the right side of my body?"

Photo by Battle Creek Sanitarium

The modern hospital has an amazing number of ingenious appliances. Above, an oxygen tent is shown. It is used for administering oxygen to patients suffering from pneumonia and other ailments.

The nerve fibers of the motor cells in the gray matter of the cortex carry the commands for action. They are the longest nerve fibers in the body, for they extend all the way down to the reflex motor centers in the spinal cord. The cells that control the movements of your big toe send their fibers all the way down to the small of the back, where the reflex motor center is located. On the way down, at the level of the hind-brain, these motor fibers cross over from one side to the other. Those from the right hemisphere pass over and enter the left side of the cord. Those from the left cross to the right. And that is why the left side of your brain takes care of the movements of the right side of your body.

Mapping the Brain

The sense organs, too, have special executive centers to which they report. Little by little nearly all these centers were mapped out by the scientists. Some of the facts were learned by experiments on animals, others in the hospitals, and still others on battlefields.

It was learned long ago that injury to a definite area of the brain causes a person to lose a particular sense. If both lobes or folds that receive the reports from the eyes are damaged, a person will go blind even though his eyes are unharmed. If one lobe only is injured, a peculiar condition will result. The man will be blind in one half of each eye. He will see one half of everything in front of him, but not the other half. In a ball game he would see the first baseman, but never the third; or depending on which lobe was injured, he would see the third but be blind to the first.

Injury to another region of the cortex results in deafness. But damage to one side of the brain does not make a person deaf in one ear only. For each ear is connected with both sides of the brain.

As we might expect, the chief centers that take care of touch and muscle sense are close to the motor centers. They are located just back of the fissure of Rolando. The center that receives the messages from your big toe is at the top of the hemisphere, while the

Photo by Battle Creek Sanitarium

The picture above shows the interior of a laboratory where experiments are carried on with guinea pigs to determine the value of certain foods and to solve various other problems connected with nutrition.

one that reads reports from your head is at the bottom.

But there are still some areas left which have no motor control. Nor do they receive reports from the senses. What is their work? In these "silent areas" the new mantle is found to be thickest of all.

It is these areas that set us apart from other animals. They are the real thinkers of the brain. They store our sense impressions, our memories. They form the moving pictures of our minds. They recollect and associate these pictures. They are the centers of our judgment. They control our feelings, learn for us, form our habits. In fact, these "association areas" are the parts of our cortex that make us human.

This master mind does not work all alone. It is a law that all the organs work together for the good of the body as a whole. And that is what happens in the cortex, where all the offices, sensory, motor, and association, are in close touch with one another.

Gall thought that the cortex was the seat of many sentiments controlled by many organs working separately. Flourens thought that it was just one organ whose parts all did the same work. The modern idea is that the cortex is made up of many parts, each with its own special function, but all joined to work together as one.

These parts are even more intimately connected than the various exchanges in a telephone system. Messages are always pouring into the offices of the chief operators in the cortex. Others are always leaving. In the brain there is always change and activity; an endless moving picture keeps going in it as long as we live. Often we may not be watching the pictures very closely, but the reel is always going, just the same, waiting for our attention.

It is this power to *attend*, to know what is going on in our own minds—in other words, to *know*—that sets us apart as individuals. Because of the way you remember, think, and act, you are the particular kind of person you happen to be. You are you.

Reading Unit No. 16

THE TELEGRAPH WIRES INSIDE US ALL

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

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What we mean by instincts, 2–393

What a "reflex act" is, 2–393-95

Why we get tired after studying hard, 2–397

How fast messages travel along nerves, 2–397

Things to Think About

How do ants illustrate what we mean by instincts?

What acts of ours are reflex actions?

Why are reflex acts done very quickly, without thinking?

How do anaesthetics prevent pain in operations?

When are reflex actions made stronger?

How can one nerve serve many muscles?

Picture Hunt

What structures enable us to know what is wrong inside us? 2 392

How can the brain control movements in your big toe? 2–393

What tissues protect the spinal cord? 2 394

Where are spinal ganglia located? 2–394-95

In what part of the spinal cord may we find gray matter? 2–395-96

How is the spinal cord protected? 2–396

Why do spinal nerves branch? 2 396

Leisure-time Activities

PROJECT NO. 1: Observe an ant nest and its members going about their tasks. Feed them some sugar to see what they do with it. Place obstacles in their path. Are they intelligent? 2–392-93

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PROJECT NO. 3: Smell a cut lemon. Do you find a reflex? 2–394

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Summary Statement

It is remarkable how quickly we act when we come in contact with hot or pointed objects. Our eyes shed tears when dust enters them. We jump at a loud noise. Our pupils expand in the dark. All this is automatic, and is called "reflex action."

The telephone wires inside this small boy have evidently been signalling frantically—sending out an "S.O.S." to say that something is wrong. And here comes the doctor to set it right.

The TELEGRAPH WIRES INSIDE US ALL

That Is Just What Our Network of Nerves May Be Called, and the Way They Work Is Nothing Less than Wondrous

THERE is no better way to begin talking about our own nerves than to talk a little first about some creatures that are very much smaller than ourselves. So we are going to begin by talking about the ants.

Ants, like bees, live together in colonies. They work together, too, for the common good of all. How well they succeed, you will see for yourself when we visit the leaf-cutting ants at home.

Each kind of leaf-cutting ant has its special work prepared for it from the very moment it is born; and there are many kinds of work that have to be done for the life of the colony.

Watch the big worker ants scramble up and down the orange tree! See how cleverly they cut pieces out of the leaves with their large scissorslike jaws! When they have finished cutting, you notice, the same scissors device lifts the bit of leaf up over the head. So they carry it, like a green umbrella, as they march home in single file. They get home by their sense of smell, following the tracks they have made in their journey out. That is easy for them, for their smelling organs are located at the base

of their feelers, quite close to the ground.

What has been happening at home while these big workers have been out gathering pieces of leaves? Their nest mates have all been busy, you can see. The leaf-cutting ants' colony is built like an underground tunnel, with many chambers, some on top of the others. The queen ants are in their special chambers laying eggs. The soldiers, largest of all the neuter ants, are ready to guard the nest from any stray intruder. If a foreign ant comes near the gates, he is immediately pierced by the saber-like jaws of one of the soldiers. How does a soldier, or any ant for that matter, know a stranger from a nest mate? Again, by the sense of smell. Different kinds of ants have a different odor, but ants that grow up in the same nest have the same odor, and so live together in peace.

The smaller workers are doing all sorts of things. Some are mending their underground home. Others are attending and feeding the grubs, or "babies" of the ant nest. See how the grubs have been placed in the chambers near the entrance, and even out of doors. They are being given their share of sun and air. At nightfall, they will be taken indoors to the lower chambers where it is warm.

Look, here are other special chambers, with tiny mushroomlike plants growing in beds. Into these subterranean hothouses the bits of leaves are brought, for the leaf-cutting ants are gardeners. Here the tiny workers chop the leaves up fine and turn them into the beds of leaf mold that you see. Other workers plant the mushrooms. Others manure it. Others weed the beds. They treat the plant in such a way that it never grows into a large mushroom, but bears little knobbed heads. These knobs are what the ants like best to eat.

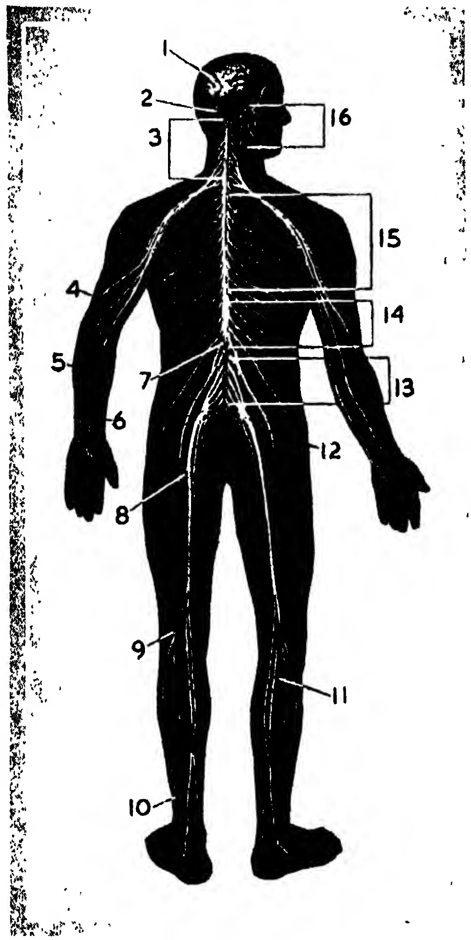


Photo by Chas. Adams Co., Inc.

Here is a diagram of the nervous system as a whole. In the head are the highest nerve centers—the cerebrum (1) and the cerebellum (2)—as well as the network of facial nerves (16). From the spinal column issue 31 pairs of nerves; 8 cervical (3), coming from the region of the neck; 12 dorsal (15), from the region of the thorax; 5 lumbar (14), 5 sacral (13), and 1 coccygeal (kŏk-sĭj'ē-ăl) (12), from the lower regions of the spine. The most important of the great nerves serving the arms and legs are also shown: median (4), ulnar (5), and radial (6) of the arm; sciatic (8), external popliteal (9), anterior tibial (10), and internal popliteal (11) of the leg.

Are these ants clever? They seem so. They seem to know exactly what they are doing, not only for the present but for the distant future. But do they?

Scientists think not. They say the actions of these animals are due solely to "instinct." That is, the animals are born with certain things they can do stamped into their nervous systems; one of these things is the cutting of the bits of leaves and the bringing of them home. Each step in the chain of these actions depends on the act that went before. Scientists call each of these steps a "reflex action."

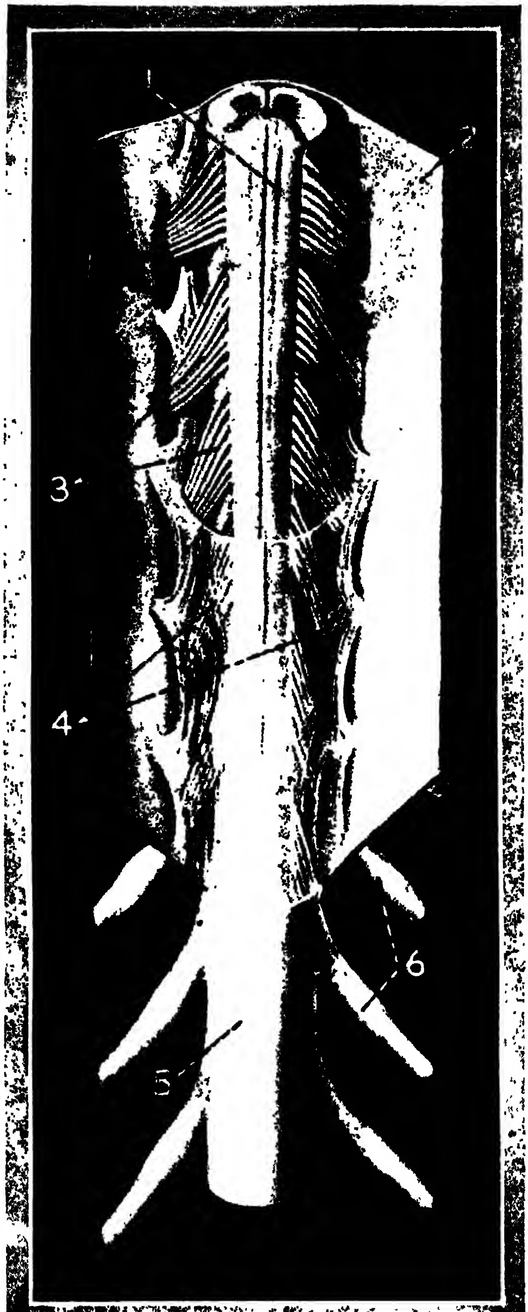
Now pulling your hand away when you have touched something hot is a reflex act, too. And a great many things that we do very quickly, without thinking, are such reflex actions.

Suppose you are walking along on a sunny day. Suddenly something whizzes past

your head. You blink. Suppose you are crossing the street, and an auto honks its horn loudly behind you. You jump. Passing a candy shop, you notice some lemon candy, the kind you like especially well. Your mouth waters. A sudden gust of wind blows a speck of dust into your eye. A tear forms.

You have blinked and jumped, your mouth and eyes have watered, all before you stopped to think, and without any act of will on your part. They are reflex actions. A reflex action is the body's immediate and automatic answer through muscle or gland to the S.O.S. calls sent in by any of its sense organs.

Let us continue. The day has suddenly grown colder. Goose flesh appears along the skin on your arms, for the tiny hair muscles in the skin have contracted. Your hands have become pale. The capillaries of the skin, contracting, have sent the blood deeper into the body. As you pass under a tunnel, your pupils grow large so that you may see in the dark. Now you are out in the sunshine again. You blink for a second, and then you see as well as ever.



Here is a piece of spinal cord cut to show its covering layers and the way the great nerves issue from it. Below, the dura mater, or outer covering (5), has been left on, but above, it has been opened and laid back (2). In the middle section the second layer, the arachnoid, has been exposed (4). Above, the arachnoid also has been taken off, leaving only the inner membrane, or pia mater, wrapped closely around the cord itself (1). The nerves issue as bundles of roots (3), then gather together into a bulb or ganglion (6), then continue as a single nerve stem.

The windows of your eyes have grown small again to let in only just enough light. You are now walking near the edge of a steep incline. When you bend over a little too far, you are jerked back into safety before you have time to think about it. Your back muscles have done that for you.

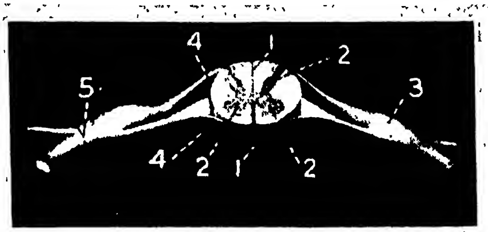
Meanwhile all your internal arrangements are working as usual. You are digesting your last meal. The muscles of the digestive tract are churning away, while the digestive juices come pouring in. All these are reflex actions. So are your breathing and the rate of your heartbeat.

These reflex acts may go on entirely without our knowledge. We digest our food without knowing anything about it. Or we may be conscious of the action, as we are when we sneeze or blink. One thing is certain: reflex actions are always quick, the muscles used in the movement all working together, and for the safety of the animal.

The S.O.S. calls are not sent directly from the sense organs to the muscles and glands. We should be nothing but nerves if that were the case. The S.O.S. messages

carried by the nerve fibers go to nerve centers. From there they are relayed on to muscle and gland. For this reason they are called "reflex." The sense effect is reflected back as motor or gland effect.

The nervous system is built like a telephone system. The "central" is in the brain and the spinal cord. The exchanges that take care of reflex actions are found in the spinal cord and in the "lower centers" of the brain. They are like the automatic exchanges of a dial telephone system, which are quicker than the ordinary kind. They have to be if they are to work so fast and well. But just as you can dial "operator" when you have trouble making your connection over the telephone, so these automatic reflex centers can make connection with the main operators when necessary. It would be a great nuisance if these operators which have their centers in the forebrain—the conscious, or knowing, part of the brain—had to take care of every little reflex act of the body: to decide whether the stomach is working properly, or whether the eyes are letting in the right amount of light. This forebrain has other work to do. It has to learn and think and will. So the lower centers do all manner of routine work, and leave the higher ones free for higher occupations.



Here is a section of spinal cord showing its structure and how a pair of spinal nerves issues from it. 1. Fissure. 2. Gray matter. 3. Ganglion. 4. Nerve roots. 5. Nerve.

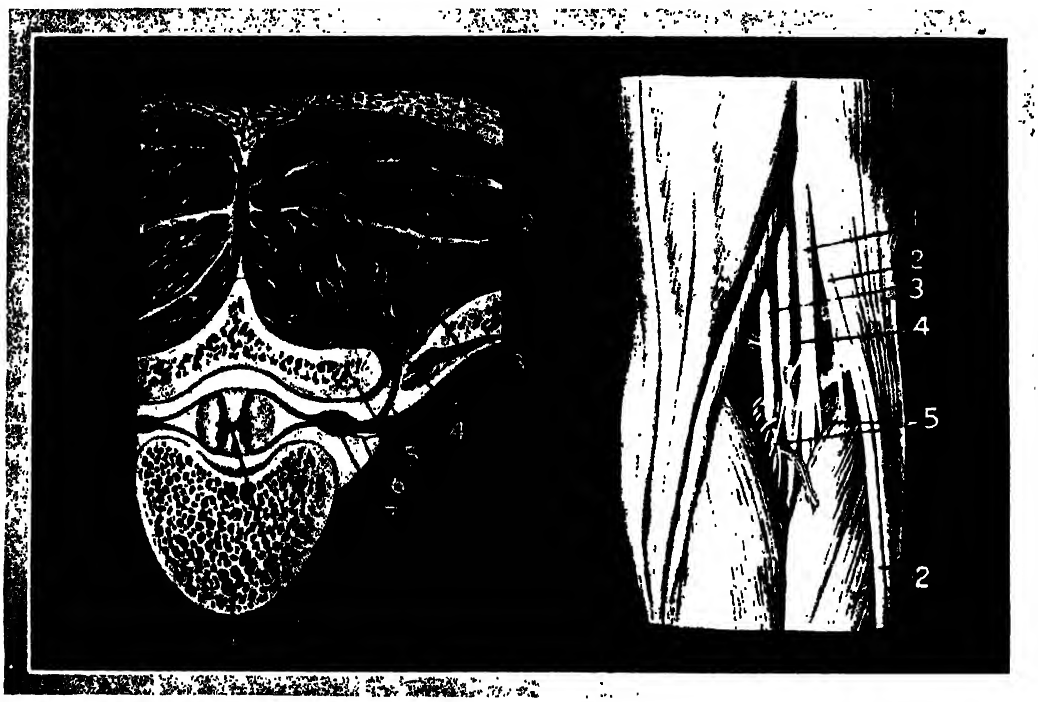
What Is a Reflex Action?

Let us trace the path of a message that results in a reflex action. Suppose you are wearing "sneakers," and, as you walk along, you step on a tack. You pull your foot away before you know you are hurt. What has happened in your nervous system? One of the receiving stations of pain in the skin of your foot felt the tack. It sent its message on through its own nerve fiber up the leg and into a part of the spinal cord, in the small of your back.

Just like a telephone wire, the nerve fiber is insulated, for it is covered by a white sheath made of a fatty substance. Almost as soon as the fiber enters the inside of the cord, it loses its white sheath and turns gray. If you study a diagram of the spinal cord in a cross section, you will see that it is round, with two deep clefts, one in front, and one in the back, and a tiny hole in the middle. The outside is white. The inside, shaped like an H, is gray. It is in the gray part that the telephone exchanges or reflex centers are found. Here are the receiving stations for such messages as have come up from your foot.

To continue our story. The nerve fiber coming from the sense organ in the skin, on entering the receiving station, loses its sheath. It develops little branches that make it look like a tree. It is an "afferent" (ăf′ēr-ĕnt) nerve fiber because it runs to the center. "Adfero" in Latin means "conduct toward." At its branching end, this afferent fiber interlaces with the ending of another nerve. The place where two nerves come into contact is called a "synapse" (sĭ-năps′). The fiber of this second nerve never wears a sheath, for it always remains in the gray matter of the cord. It is part of the reflex center. It, in turn, crosses over till it meets with still another nerve. This last is "efferent" (ĕf′ēr-ĕnt), meaning "carrying away," for its fiber runs away from the center. It runs down to the muscles of the leg. Along this nerve the command to work is put through. The leg muscles contract, and the leg is pulled away before you have had time to think.

If any part of a reflex pathway from sense organ to center and back again is broken, the messages cannot get through. Cocaine, for instance, puts the sense organs out of order, and blocks the pathway at its beginning. Stronger anaesthetics (ăn′ĕs-thĕt′-ĭk) stop the conduction of messages through the sensory fiber, that is, through the fiber of the sense nerves. So do cutting of the fiber and damage due to disease. The



At the left above is a section of the spinal column with the spinal cord inside it, showing how they fit together. 1. Skin. 2. Muscular tissue of the back. 3. Rib. 4. Branches of a spinal nerve. 5, 9. Vertebra of spinal column. 6. Spinal nerve. 7. Ganglion. 8. Gray matter within spinal cord. At the right above is a picture of the outer layer of nerves and blood vessels back of the knee; it should give us some idea of how closely the nerves, arteries, and veins lie together all over our bodies. 1. Tibial nerve. 2. Peroneal nerve. 3. Popliteal artery. 4. Popliteal vein. 5. Branches of the tibial nerve. The surrounding tissue is muscle

spinal cord itself may be diseased, as when the hole in its center enlarges, squeezing the nerves so that they cannot work. The motor nerves—those that control the muscles—may be destroyed by infantile paralysis. Or they may be put to sleep by a very strong drug called curare (kōō-rä'rē). The natives of the Amazon know this drug. They use it to poison their arrows. The tiniest bit of curare on the tip of an arrow is so powerful that when it enters the body of man or animal, the muscles are paralyzed. The victim smothers because the muscles that control breathing cannot work.

The Work of the Sensory Nerves

After you have stepped on a tack, you know about it soon enough. For inside the gray matter, the sensory (sĕn'sō-rĭ) nerve carrying its S.O.S. messages of pain makes contact with another nerve. This nerve, donning its sheath, runs upward through the white matter to a higher center in the brain. The message at last reaches a main operator, and you discover that you have been hurt.

All the muscles of the body keep up a constant telephone exchange with the centers. They tell central what is happening to them. In return, central sees to it that they are kept in a state of tone, neither too flabby nor too tense, but ready to act at need.

Why Muscles Work in Pairs

Suppose all the muscles of the leg that felt the tack received the same motor message from center. The leg would stiffen entirely. It could not do what it needed to do. But muscles work in pairs. When one contracts, its partner relaxes. That makes for harmonious movement, and it is the nervous system that sees to it. For the higher centers of the brain influence the lower reflex centers. No one yet knows exactly how. The nerves from the lower centers carry two sets of messages to the muscles. One tells some of them to set to work. The otner tells their partners to stop or relax;

and all because of the messages to their central from the brain.

We have many reflexes in the body, but only a certain number of muscles. Many reflexes therefore use the same muscles. Tickle an old dog between the shoulders, and he will start to scratch himself with a hind leg as though a flea had bitten him. While he is doing that, pinch the paw he is using. He will stop scratching, and immediately pull his leg away. For two reflex acts using the same muscles cannot take place at the same time. The strongest wins. Usually it is the one that is most necessary for the good of the body. It was more important for the dog to keep from being hurt than to scratch the flea from his back.

The brain also sends messages that increase the strength of a reflex action. Sit down and cross your legs; then get someone to give you a little tap with the edge of his hand just below the knee cap. Your leg jerks up very quickly. Try as you will, you cannot stop it. This time the S.O.S. messages have come from the sense or muscle spindles deep inside the leg. Now clench your fists and have your friend tap the same spot. The jerk is even faster and strong. Somehow it has been reinforced by messages from the higher parts of the brain.

It is the messages from the brain that get the right of way. The operators are still automatic and reflex, but those in the spinal cord are the subordinate ones. That is where we differ from the lower animals. Their spinal reflexes are more pronounced and work more independently.

Here is another way that man gets ahead of the beasts. His nervous system has the power of forming more and more new reflexes. That gives him the power to learn, a power that has placed him at the head of the animal kingdom.

Nerve fibers do not run to their destinations singly. Neither do the telephone wires that connect your house with central. Telephone wires are built into cables. Nerve fibers are built into nerves. Hundreds of thousands of little fibers, each one a tenth the thickness of one of your hairs, are bundled together to form a muscle. But the fibers of a muscle all work together, and this is not so in a nerve, for each nerve fiber is independent. In a single nerve there may be fibers that will reach the heart, the stomach, the intestines, and still other organs, and all these fibers must be independent of one another. Yet they are all parts of one nerve.

When nerves are excited or stimulated at their ends, it is their duty to carry messages. But you know very well from experience that nerves can be excited anywhere along their course. When you bang your "funny bone" you strike the nerve that runs to your fingers so that it tingles all the way down.

Certain things hinder the messages that travel along the nerves. If a message has just passed along a certain nerve fiber, the fiber will be unable to carry another for twenty-five ten-thousandths of a second. Carbon dioxide prevents a nerve from working. So do chloroform and ether.

To keep a nerve working properly, the substance that it must have above all is oxygen. Without oxygen no work can be done. The nerve fiber must have plenty of oxygen and keep free of carbon dioxide. When it has too little of one or too much of the other, we get "fatigued," or tired. After you have studied too long, or have been too much excited, you begin to have a tired feeling. Your nervous system has been working too hard. It has not had time to clear away all the waste products formed by its work, especially the carbon dioxide. Sleep is the best cure for this kind of weariness. It gives the nervous system a rest, so that the products of its overwork may be washed away by the blood.

Now we have come to the part that is hardest to understand. In what form do the messages travel over a nerve? The messages go very fast. They go about 400 feet a second, or nearly 280 miles an hour. Almost surely they are partly electrical in nature, though of course they travel far less rapidly than an electric current. They would seem to be partly electrical and partly chemical. So much is fairly sure. But about the way messages travel along our nerves we know very little. We have a great deal left to discover.

FIRST AID

Reading Unit No. 1

HOW TO GIVE FIRST AID

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

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Speed and a cool head, 2–399-400
Sending for a doctor, 2–399-400, 404-5
Why patients should not be moved, 2–400
Carrying the injured in an emergency, 2–400-1
Nosebleed, ivy and oak poisoning, burns, splinters, cuts, and scratches, 2–403-6
Fainting, sunstroke, and poisoning, 2–404, 408
Artificial respiration, 2–408-11

Things to Think About

Why should a doctor always be called in case of accident?
Why should you never give up hope when using artificial respiration?
Why is it necessary to apply artificial respiration immediately after a person is recovered from the water?
How should snake bites be treated?

Picture Hunt

What is the best way to remove a drowning person from the water? 2–409
What are the different methods of bandaging? 2–401-7, 411
What are some emergency methods for moving injured people? 2–400

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What are some poisonous drugs? 2–396
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What steps should you take in helping an injured person? 2–399-411
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Leisure-time Activities

PROJECT NO. 1: Practice life saving under the direction of a Red Cross examiner, 2–408-10.

PROJECT NO. 2: Make and apply different types of bandages, 2–401-11.

Photo by British Information Services

A bomb has smashed a London building during the "blitz," and some of its unlucky occupants have been hurt. This one, at least, will pull through, thanks to prompt first aid rendered by an alert and well-trained ambulance team, which has courage and coolness as well as knowledge. Such swift help will save many lives among the victims. Even one who does not know much about administering first aid can do a great deal for a person suffering from shock just by talking to the patient. A continous flow of quiet, reassuring talk will calm and steady the nerves of the sufferer and will help greatly to bring about his quick recovery.

HOW *to* GIVE FIRST AID

Sometime You May Find a Life Depending on Your Quick, Efficient Help. When That Time Comes, Will You Know What to Do?

A FRENZIED shrieking of brakes—a sudden cry—and there on the street corner is a knot of anxious bystanders gathering about a huddled form on the ground. All is confusion for a moment, with everyone crowding about the victim, and nobody knowing just what to do. Then suddenly someone pushes through the crowd. "You, there, go to the drug store across the street and call a doctor," he cries. "And all you people stand back. Give the poor creature air!" And as the crowd pushes back with a sigh of relief at having found a leader, the man bends over the form on the ground to see what is to be done before the doctor and the ambulance arrive.

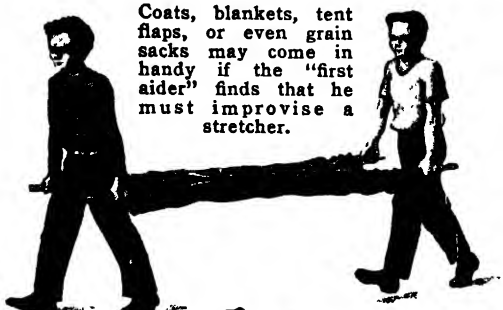
That is first aid. It takes a cool head, firm courage, and sure but simple knowledge. We can all learn it; and if we do not, we shall some day be almost certain to wish that we had. For first aid has saved untold suffering and many a life.

It takes a cool head. Getting flustered will not help at all. There is usually plenty of time to think what is to be done. Even if you have to give the victim a quick antidote for poison, it will not help matters if you get excited and give him the wrong one. Act quickly, but keep cool.

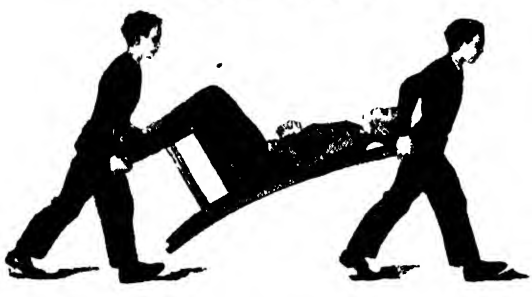
It takes firm courage. You may have to quiet others who have lost their heads from grief or mere excitement. And you will have to take responsibility. The first thing you will do, of course, will be to send for a doctor if it is at all possible. Even if you are not sure the injury is serious, you must not take

any chances; send for a doctor anyway. But before he arrives, you will have to stay in charge, and if you are going to be a good "first-aider" you must not flinch.

It takes sure knowledge. If you do not know what to do, no amount of courage and coolness can help you to do it. Fortunately, what you need to know is very simple, after all. If you will study the following directions carefully, and then come back to them later and read them again, you may some day be able to soothe a terrible pain, or even save a life.


Coats, blankets, tent flaps, or even grain sacks may come in handy if the "first aider" finds that he must improvise a stretcher.

Once you have sent for a doctor, the first rule is to give the patient plenty of air. That means keeping the crowd at a distance, if there is a crowd. It means throwing open windows if you are inside a house. It means loosening any tight clothing which may interfere with breathing. Loosen the injured person's clothing very gently, of course, taking care not to move the injured part. You may have to cut the clothing away. You will not spoil a garment, naturally, unless it seems necessary; but if an injury is serious, such things as clothes become of small account.


Here are two ways to carry a wounded friend—provided he does not require a stretcher. If there is no chair handy, two of you can make a seat, or "pack saddle," with your hands. Each of the two carriers grasps first his right wrist with his left hand and then the left wrist of the other carrier with his right hand. Of course, to carry your patient upon a chair, as shown just above, is even better.

If the injured person is in a safe place, it is usually wiser to leave him where he is. Moving him will almost surely give him pain, and if he has broken bones, or is bleeding badly, it may do him a great deal of harm. If he is badly injured, keep him flat on his back. If his face is pale and he feels faint, lower his head a little below the rest of his body. If his face is flushed, raise it slightly. If his face is pale and his skin clammy, if his pulse comes quickly and he cannot breath deeply, he is suffering from shock. Then keep him warm—with blankets, hot water bottles, hot drinks, and perhaps, if it is handy, half a teaspoonful of aromatic spirits of ammonia in a cup of hot water. But if he is unconscious, never try to force liquid down his throat, for it may choke him.

If you have to move your patient, be as careful as you possibly can. If he is conscious, every false movement may mean a stab of pain; conscious or unconscious, he may suffer worse injury if any broken or bruised part is wrongly handled. You will have to decide on the method of moving him according to his injury and according to what you have to work with.

A badly injured person should, if possible, be moved on a stretcher. There is not likely to be a regular stretcher at hand, of course, but many makeshifts will occur to the clever first aider. Perhaps there is a light door, a plank, a shutter, or a gate which may be requisitioned to lay the patient on. If there are grain or flour bags handy, those will serve. Cut a hole in each of the two bottom corners of the bag, and then pass a pole of some sort into each side of the mouth of the bag and out through the hole at the bottom on the same side. Or you may use two stout coats, borrowed perhaps from the bystanders. Turn the sleeves wrong side out, slip poles through the sleeves, and then button the coats to-

Anyone can learn how to make a neat, firm bandage, but of course the time to begin practicing is not when someone is hurt! Fig. 1a. By turning the bandage as it is applied, it can be made to fit the limb. Fig. 1b. The bandage should be firm but not too tight. Figs. 2a and 2b. Two ways to bind an elbow. In 2a one begins at the center and works outward, laying strips alternately above and below the elbow. In 2b one begins at the edges, and lays strips alternately above and below, working toward the center.

gether over the poles. A skirt or two slipped over poles will also serve, as will a strip of heavy cloth, a sheet, or a blanket. Of course, your improvised stretcher must be well tested to make sure that it will be strong enough to hold the patient, for nothing could be more disastrous than to have it give way and let him fall.

How to Make a "Pack Saddle"

If your patient is not very badly hurt, two of you may make a seat or "pack saddle" with your hands. You have probably made this kind of seat for years in your play. In case you do not know how, here is the way to do it: Each of the two carriers grasps first his right wrist with his left hand, and then the left wrist of the other carrier with his right hand. On the seat made by the four hands thus joined, the patient may ride in fair comfort, especially if he is able to put his arms about your necks to steady himself.

A chair, preferably a simple, straight-backed one, makes a good carrier for an injured person. He sits in the chair, with his hands in his lap. One of you grasps the front legs of the chair and the other the top corners of the back. You can take hold in such a way that you will both be facing forward as you walk, and that will make the going much easier for everybody concerned.

Using the Fireman's Lift

It may happen, however, that you will be the only sound person at hand, with no chance of getting anyone to help you carry a chair or make a pack saddle. Then, if you are strong enough, you may use the fireman's lift. This method of carrying an injured person takes its name from the fact that firemen

use it in rescuing people from burning buildings. If your patient is on the ground, you must first raise him to his knees, when that is at all possible. For this purpose you must lay him, gently, face downward. Step astride his body, with your face toward his head, and, putting your hands under his armpits, lift him to his knees. Then put your right shoulder against the patient's abdomen and draw his left arm around your neck so that his left side rests against your body and is supported by your right arm held about his waist. Now, clasp his right wrist with your left hand, put your right arm about his right thigh, and quickly lift him to your shoulders. Take his right wrist in your right hand and his left hand in your left hand so as to balance him against your own body. This is rather complicated, as you see, and you had better practice it on your friends with the directions before you, or you will never be able to do it should one of your friends get hurt sometime when you are off in the woods together.

So far we have been talking in general terms, without much attention to the exact kind of trouble which may have come upon the person you are helping. But to be a good first-aider you must know what to do for different kinds of accidents. If you read what follows very carefully, and make sure you undeistand it, you ought not to have very much difficulty remembering the most important points when the time comes.

WHAT THE HOME MEDICINE CABINET SHOULD HOLD

Absorbent cotton
Gauze bandaging
Ready-made bandages for small cuts
Triangular bandages
Scissors for cutting bandages—these should be sterilized by boiling
Adhesive plaster
Safety pins
Diluted tincture of iodine—*poison*—for external use only
Pure grain alcohol
Aromatic spirits of ammonia
Vaseline
Unguentine
Camphorated ointment
Castor oil
Cascara
Aspirin
Epsom salts
Bicarbonate of soda
Brown-mixture lozenges for coughs
Hot-water bottle
Fountain syringe
Mustard
Table salt

THE CAMPER'S FIRST-AID KIT

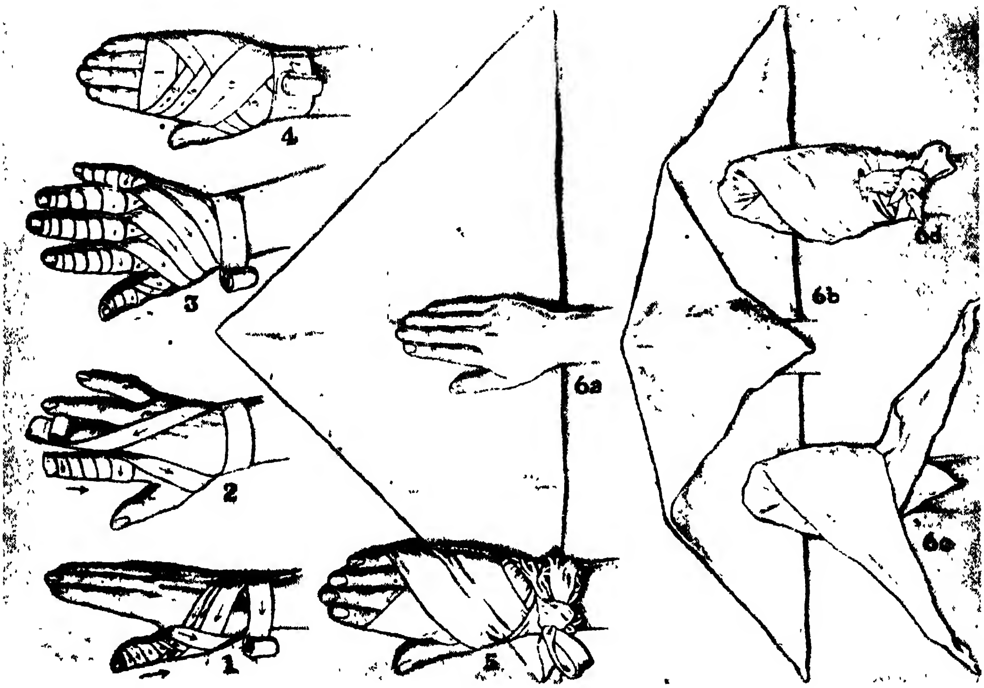
Ready-made bandages for small cuts
Ampoules of tincture of iodine in wooden container—*poison.*
Unguentine
Cascara tablets
Castor oil
Serum for snake bite
Assorted bandages
Absorbent cotton
Adhesive tape
Safety pins
Bicarbonate of soda
Small amount of pure grain alcohol

Above are some of the more useful things to have in the medicine chest at home or in camp. If your home is far from a drug store you will want, perhaps, to keep more things on hand. Ask your doctor to make out a list. The camper's first-aid kit should be air-tight and germ-free. The first four articles are essential. A suitable serum, to be used for the bite of a poisonous snake, should be included if you are going into a "snake country." Aromatic spirits of ammonia may be taken—one-half teaspoonful in half a glass of water—for shock or faintness. Mustard and salt may appear to belong more properly in the kitchen but a small supply kept in the medicine chest may one day prove very useful. In case of poisoning, a heaping teaspoonful of mustard or salt in a cupful of lukewarm water will bring about vomiting. Salt is useful as a gargle or for stopping nosebleed, and may also be used on the toothbrush.

Bruises, strains, and sprains. Wash a bruised or strained part gently. Unless the injury is very slight, the next thing to do is to lay on it cloths wrung out of very hot or very cold water, or to bathe it with the water directly. Use hot water rather than cold if your patient is weak, or if he is very young or very old. If you use hot water, be sure not to get it so hot that it will burn; anything you can hold your bare wrist in will be all right. If the pain continues and the injured part begins to swell rapidly, you must call a doctor.

Sprains, which are really severe strains, are treated in much the same way. Use the hot or cold applications, but raise up the sprained joint a little before you apply the water, and bandage it firmly afterward. If the sprain is very bad, you should have the doctor replace your bandage by a more scientific one.

Choking. You have probably been slapped on the back between the shoulder blades often enough yourself when you started to choke. The idea is to jar loose the fish bone or whatever else has blocked the passage of the throat. If slapping does not work, try to get the patient's head lower than his feet so that the thing that is choking him can



Photos by Clay-Adams Co., Inc

Hands seem to have a faculty for getting into trouble; and once in trouble, they should be kept free from infection. Figs. 1, 2, 3, and 4 show you how to bandage the fingers and lower part of the hand with a regular strip bandage. Figs. 5, 6a, 6b, 6c, and 6d show you how a bit of cloth or a handkerchief folded into a triangle—and disinfected!—may be used to bandage the whole hand.

drop out more easily. A little child can be picked up by the heels and held head downward while his back is slapped; many a safety pin has been dislodged by this rough-and-ready method. If that cannot be done, you had better try to get hold of the obstructing object with your fingers.

Remedies for Homely Ills

Hiccups. If you get hiccups, it is usually because you have eaten too much or for some other reason have not been able to digest your food properly. They can commonly be stopped by holding the breath for a minute or so, or by swallowing slowly and hard, perhaps with your fingers pinching your nose to make sure that the effect of the swallow goes all the right way. If that fails, get someone to hold a glass of water to your lips while you drink it all down without once taking your breath. While you are drinking it—and this is very important—press the tips of your little fingers firmly into your ears. If all these remedies fail and the hiccuping continues a long time, it may be necessary to take something to make your stomach throw up whatever is upsetting it. If the hiccups keep up for twelve hours or so, call a doctor; such a case is really serious.

Nosebleed. Never blow your nose when it is bleeding; blowing it will make it worse. Loosen any tight clothing around the neck, hold the head erect or lay it back over the edge of a chair, and apply something cold to the back of the neck and the bridge of the nose. A metal key or a cloth wrung out of cold water will serve. If this is not enough, salt water snuffed up the nose should help, or, if that too fails, a pack of cotton or gauze may be placed loosely in the nostrils. But if the nosebleed is as stubborn as this, you had better send for the doctor.

Ivy or oak poisoning. Of course the best thing for ivy poisoning is to keep away from

poison ivy, remembering that an ounce of prevention is worth a pound of cure. Poison ivy has three leaves, and the harmless kinds of ivy have five; so you should not have much trouble telling them apart if you keep your eyes open. But if you should come home some day with ivy poisoning, treat it as quickly as possible, for it spreads. Wash the affected part with very strong soap and hot water, and spread carbolized vaseline on it; or apply a paste made by mixing baking soda with water. A solution of boracic acid or of Epsom salts will do as well. These things are good for taking the soreness or itching out of almost any skin affection. If the ivy poison spreads instead of getting better, go to a doctor at once. Poison ivy administered internally by a physician is a practically certain cure.

Aids for Fainting and Sunstroke

Fainting. A person who feels faint should sit down as quickly as possible and put his head forward, even between his knees. He should have plenty of fresh air. Fresh air is very important, too, for anyone who has actually fainted away. So throw open windows, or, if there is a crowd, make it get back out of the way. Lay the patient on his back with his head a little lower than his body. Loosen his clothing, especially around his throat, where a collar may interfere with his breathing. Sprinkle his face and chest with cold water. Rub his limbs, moving your hands always toward the heart. If possible, hold smelling salts to his nose, or give him a few gentle whiffs of ammonia. Do not try to make him drink anything until he is thoroughly conscious.

Heat exhaustion and sunstroke. A person exhausted by heat is treated just like an injured person suffering from shock. His skin will be cold and clammy, his pulse irregular, and he will feel giddy and may become unconscious. Get him to lie down, with his head lower than his body. Of course he should be kept in a cool place, if that is possible. Loosen his clothing wherever it is tight, and rub his limbs to make his blood flow normally again. Odd as it sounds, when your patient is suffering from too much heat, his exhaustion must be treated bv more heat. Apply cloths wrung out in hot water, and give him hot drinks, such as coffee, tea, hot milk, or hot water.

Sunstroke is a very different thing. Your patient's face will be greatly flushed and his pulse very rapid. He will feel giddy and may quickly become unconscious. He may even go into convulsions. It is a serious matter, and a doctor should be called at once. Meanwhile lay your patient in as shady a place as you can find. Loosen or remove his clothing. Then apply cold water, or ice if it is to be had, under his arms and on his face, neck, wrists, and chest. When he regains consciousness, give him plenty of cool water to drink. Do not give him stimulants, such as whisky or even coffee, but just cold water.

Frostbite and Freezing. Frostbite has to be treated with cold, just as heat exhaustion has to be treated with heat. Rub the frostbitten parts with snow if snow is handy; otherwise use cloths wrung out of very cold water. You must rub gently or you may tear the skin that has been made tender by its hurt. As the circulation begins to grow more nearly normal, you may gradually begin to use water that is not quite so cold; but do not think of applying water that is even tepid—too much warmth at once may cause serious harm. When the circulation has been fully restored—usually a matter of several hours—you should rub the affected parts with carbolized vaseline and cover them with soft bandaging.

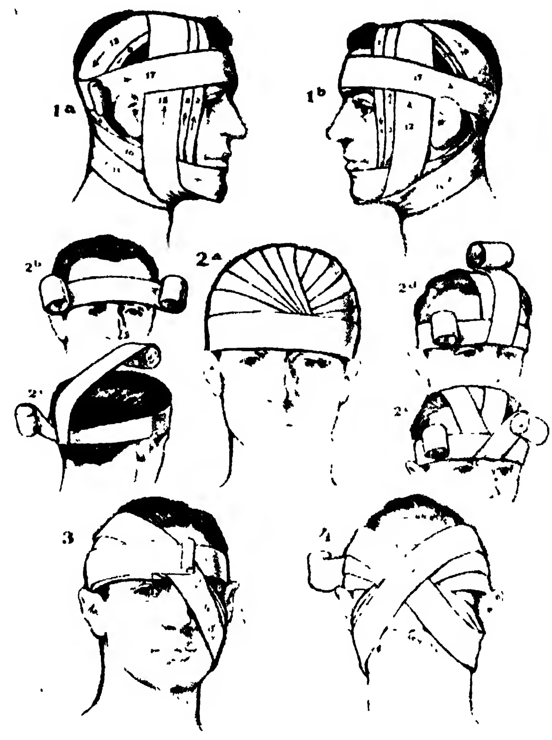
When a Doctor Is Needed

If the part is not only bitten by frost, but really frozen, the case is serious and you should call a doctor at once. Lay your patient down in a cold room, and go ahead as for frostbite. As the circulation grows nearer normal, the temperature of the room may be raised a trifle. By that time, too, the patient may be given some sort of stimulant and a hot drink of some kind. He should then be kept warmly covered in bed.

Burns and scalds. Even a little burn or scald is painful, and an extensive burn is always serious. Sunburn is as much a burn as if it had been caused by a hot object much nearer than the sun. Bad sunburn is certainly a good thing to avoid, and extreme

cases may cause death. If you do get badly sunburned, you should treat the injury just as you would treat any other burn or scald. In sunburn, as in all kinds of burns, the amount of skin surface affected, rather than the depth of the burn, is always the thing that makes the matter more or less serious.

To ease the pain of a burn, the great thing is to protect it from the air. Spread a soothing application on it first; a paste of baking soda and water, unguentine, a solution of Epsom salts, or in an emergency any pure oil, will do. Then bandage the affected part very loosely with a clean cotton cloth or gauze. A second bandage, also loose, may be used to keep the first in place if necessary. Never put loose cotton on a burn; it will stick. An excellent lotion for burns may be made by mixing equal parts of raw linseed oil and lime water; but this should be prepared by a druggist. A doctor can give you other remedies.



Photos by Clay-Adams Co., Inc

"Jack fell down and broke his crown, and Jill"—instead of "tumbling after"—carefully wrapped it up for him! Figs. 1a and 1b show how to bandage the head and chin. The strips are numbered in the order in which they were put on, and the arrows show their direction. Figs. 2b through 2e show how to make the cap bandage at 2a. Figs. 3 and 4 illustrate how to bandage one or both of the eyes.

If the burn is not from heat but from an acid or an alkali (ăl′kȧ-lī), you must get the surface clean before you try to heal it. Pour cool water over it first. Then the acid which is left has to be neutralized. This can be done by pouring on it a solution of baking powder and water, or a solution of weakened ammonia; even pure soapsuds are better than nothing if the other things are not at hand. If the acid was carbolic, you should, if possible, use alcohol. If the burn is from alkali, apply lemon juice or vinegar. After you have thus cleansed and neutralized the burn, treat it like any other.

When the skin has been broken, burns must be even more delicately handled. Use olive oil, castor oil, carbolized vaseline, or clean lard; soak the bandages in oil. Never touch any burned surface with anything that is not absolutely clean and sterile.

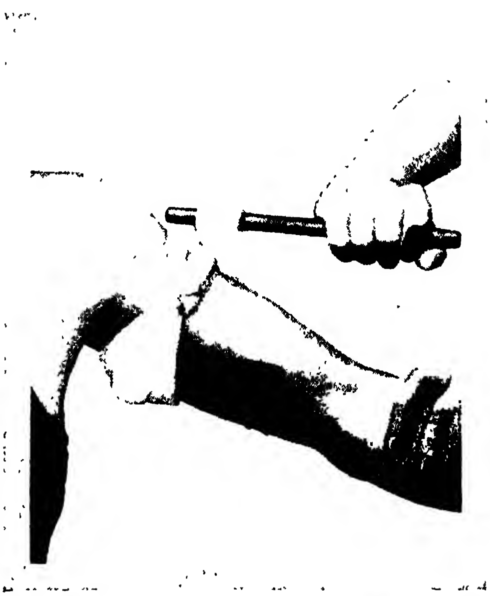
Splinters. A good way to remove a splinter is to hold a knife blade against it, and then pull it out with the fingers. Sometimes you can pull it out with the finger nails alone. Sometimes you have to prick the skin or even probe beneath it with a needle in order to get hold of the thing. If you use a needle, sterilize it first by dipping it in antiseptic or holding it for a moment in a flame. You do not have to use it hot—it will still be sterile when it cools—but be sure it is sterile.

Cuts, scratches, wounds. Of course we do not have to call a doctor every time the cat scratches our fingers. But it is a very good thing to remember that even the tiniest cut or scratch, if it gets dirty and infected, may unexpectedly make one very ill indeed. So it is better to treat every break in the skin with an antiseptic, or germ killer. Wash your hands thoroughly before you touch the wound. Then pour some good antiseptic.

such as a weak solution of iodine, over the injured part and wrap it up with a sterile cloth or gauze.

If the wound is serious, send for the doctor. Probably all you need to do before he comes is to cut away clothing from the wound and let it alone. If it is bleeding normally, the blood will carry away the germs and impurities with it. If it is necessary to touch the wound at all, be very sure that anything you touch it with is quite sterile; hands should be thoroughly washed and the nails scrubbed with a nailbrush. But if the doctor can come at once, you had probably better not touch the wound at all.

Serious bleeding. A certain amount of bleeding helps to cleanse a wound, but too great a loss of blood is of course dangerous. So you may have to bandage a wound snugly with clean gauze to stop the bleeding, or place a dressing over it and press down on it with the hand. The dressing must be sterile, of course, and the hands scrupulously clean. If the bleeding is more serious, you may have to press firmly against the vein that has been cut. If pressure of this sort does not stop the flow, you will have to use a tourniquet if the wound is in a limb.



This picture shows you how to apply a tourniquet to stop the flow of blood from an artery. The first rule is to apply it an inch or so from the wound and between the wound and its source of blood supply, the heart. Anyone knows that if you step on a rubber garden hose, the water will stop running through it. An artery is rather like a garden hose in that if you press on it, the blood will stop flowing. Now of course to do this you must know the position and course of the larger arteries. And unless you are skillful you may do more damage than good. This article will tell you how to use a tourniquet with safety.

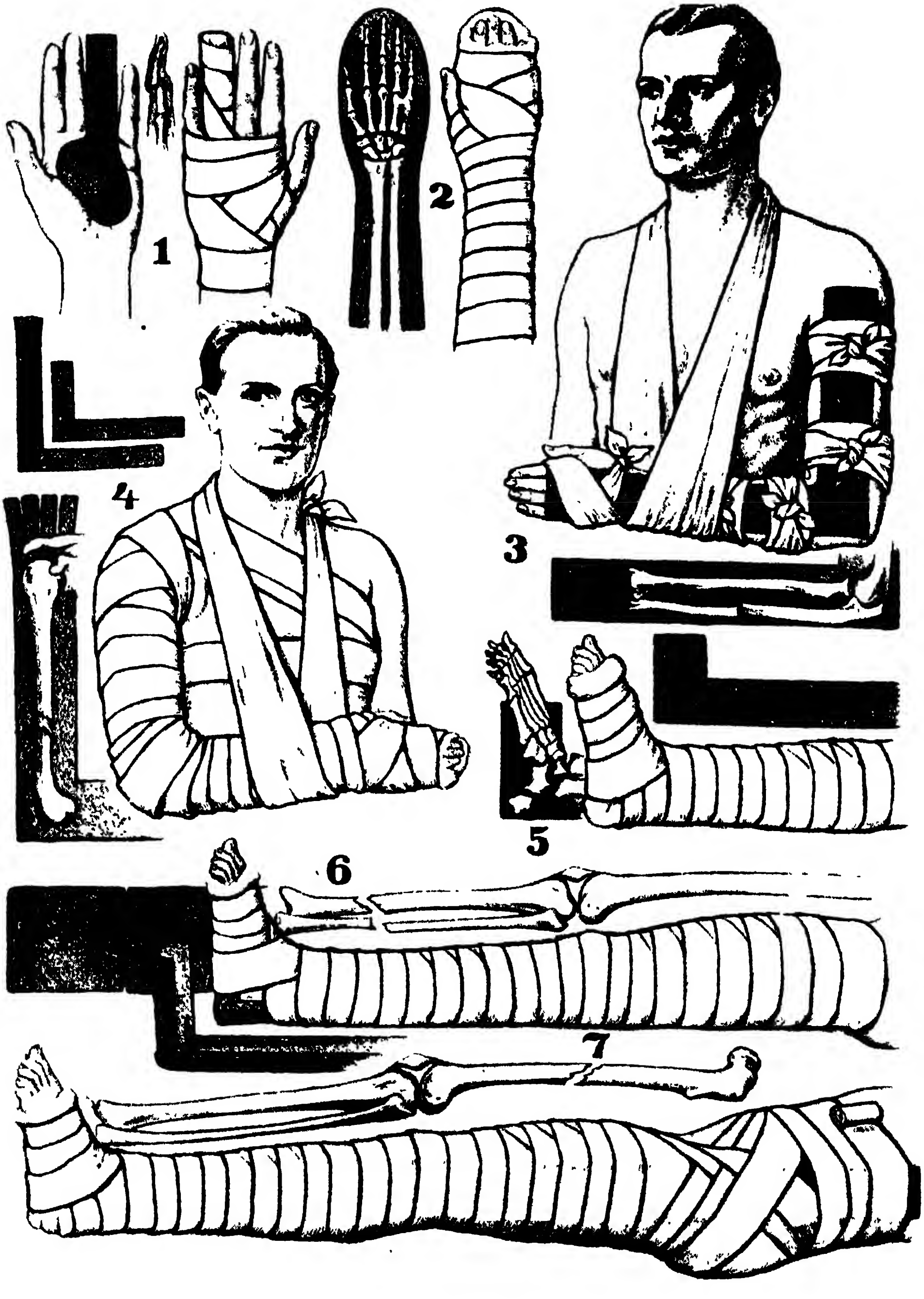
How to Stop Bleeding

A tourniquet (tōōr′nĭ-kĕt), quickly and efficiently applied, has saved many a life. It is used to stop bleeding from severed arteries. To make the best use of it, you need to know the position and the course of the larger arteries; and nearly every boy and girl learns that in school. The tourniquet is simply a mechanical device for applying pressure. You need a piece of stout cord or rope, or else a strip of cloth such as a handkerchief, a towel, a necktie, or part of a garment; you need also a short stick and a small hard object such as a stone or a little piece of wood. Tie the cord loosely about the injured limb, between the wound and the heart. Then place the small stone or bit of wood between the cord and the body, just above the cut in the artery. Next, insert the short stick. Now twist the stick slowly and carefully, holding the pad in place as you do so. By this means you can exert much more pressure than you could with the fingers alone. The pressure ought to stop the flow of blood at once.

If the doctor is long in coming, you ought to loosen the tourniquet a little, say every fifteen minutes, to let some blood flow. For if the circulation is wholly cut off for too long, there is great danger of gangrene setting in. But if the wound still bleeds much when you loosen the tourniquet, you must soon tighten it up again.

Dislocations. A dislocated bone is one which has been pushed or pulled out of its socket. If you try to put such a bone back yourself, you are likely to tear something inside, a ligament perhaps. So it is better to call a doctor at once. While you are waiting for him, try to sooth the patient's pain by laying cloths wrung out of very hot or very cold water on the injured region, as for a sprain. These hot or cold applications are meant to relieve soreness, inflammation, and swelling.

Broken bones. The injury from a broken



Photos by Clay-Adams Co., Inc.

This page shows how to bandage broken bones. Now no "first aider" has the knowledge and skill necessary to set a broken bone, but by knowing where to put a support, he can relieve the sufferer of some pain while he is waiting for the doctor to come. No. 1. Bandage for dislocated finger. No. 2. For broken bones in the hand. Nos. 3 and 4. For breakage below or above elbow. No. 5. Support for injured heel. No. 6. Bandage for breakage below the knee. No. 7. For breakage above the knee.

bone is technically called a fracture. When a bone has been broken but has not pierced the flesh, we call it a simple fracture. When the broken end has torn out through the flesh, the fracture is compound; for then there is not only a broken bone to be set, but an ugly wound to treat, too, with all the dangers of infection.

Of course you will not try to set a broken bone, but will send for the doctor at once. Meanwhile keep the patient still in order to avoid unnecessary pain and to keep the bone ends from being pulled even more out of place. If the fracture is simple, you may perhaps ease the patient by making very simple splints; that is, by fastening something stiff along a broken leg or arm to hold it straight and to prevent the nearest joint from being bent. A strip of light board or heavy pasteboard, an umbrella or a cane, may be bound along the limb; but be careful to bind it loosely enough to allow for swelling, and pad it where it lies against the skin. If the fracture is compound, the wound may require attention just like any other wound, and the person is almost sure to need treatment for shock. That is about all you can do for him.

What to Do for Poisoning

Poisoning. Quick action is important in treating poisoning; *quick* action, but not merely hurried confusion. Call a doctor at once, and tell him over the telephone what poison the patient has taken, and how much of it. He will tell you what to do before he gets to you. But since you may not be able to get a doctor at once, it is a good thing to know the antidotes for the more common poisons, or at least to have a list of them handy. You are pretty safe, whatever the poison, in immediately giving the patient an emetic; that is, something to make him vomit and thus empty his stomach of the poison in it. Mix a teaspoonful of mustard in a cup of warm water, and have your patient drink it. Keep on dosing him with this, and have him drink quarts of warm water—to wash out his stomach, you see. Another way to make a person vomit is to run your finger down his throat. He must somehow be made to throw up the poison.

Snake bites. A very special kind of poisoning which you may have to deal with if you are a camper or a woodsman is snake bite. The treatment for the bite of the copperhead and the rattlesnake is fortunately the same. Such a bite is usually in a leg or arm, which the snake has struck at as you strode through the bushes or climbed over the rocks.

How to Treat Snake Bites

The first and most important thing is to cut off the circulation so that the poison cannot go all through the blood. Apply a tourniquet, as for a cut artery. Then squeeze and suck the wound to get the poison out. Taking the poison into your mouth by sucking—you will naturally spit it right out—is dangerous, though it will not hurt you unless you have a bad tooth or a cut somewhere through which the poison can get into the blood. Cut the flesh around the bite in order that you may suck out the poison better. It will hurt a little, but it has to be done. If necessary, you may cauterize the wound with a piece of hot metal or stone. A serum may be given, but this must be fresh. A serum which has been kept long is almost entirely useless. Not alcohol, but a stimulant such as strong black coffee, may be given to strengthen the heart action. The tourniquet must not be taken off for some time even after the cauterizing; but you must loosen it from time to time in order to let a little blood flow through.

Drowning. If you spend your vacation by the water instead of in the woods, it is drowning rather than snake bites that you have to watch out for. The main point is to understand how to administer artificial respiration; that is, how to make the half-drowned person breathe until he begins once more to do it of his own accord. Meanwhile, of course, you must send for a doctor.

Artificial Respiration

The Schaefer method of artificial respiration is one of the simplest to learn and needs only one operator. First lift your patient by putting your hands under his stomach and let his head hang forward, face down, until the water has run out of his lungs. Then lay him on the ground, face downward, with one

If a drowning person seizes you by the wrists while you are trying to rescue him, bring your feet against his chest and push him away.

If he grasps you around the neck, put your hands against his chest, pushing away and ducking from under his arms at the same time.

If the person to be rescued grasps you around the neck from the rear, you can get an advantage over him by grasping his thumb firmly.

When you have seized the victim's thumb, push his arm back as the picture shows you, turning around to face him at the same time.

Once turned around, you can push away from him by placing a hand on his chest. A rescuer is in no danger if he is cool-headed and remembers always to approach a drowning person from the rear.

If the person to be rescued is in a frame of mind to do what you tell him, have him lie on his back with feet apart, placing his hands on your shoulders. Then push him ahead of you using the breast stroke

The best way to rescue a person who is struggling wildly is to use the "full-Nelson carry," which is shown in the picture above.

Begin working at once to revive a drowning man. The loss of a few seconds may mean the loss of his life. Above, artificial respiration is being used.

Photos by American Sports Publishing Co.

Photo by Boy Scouts of America

The best method of administering artificial respiration is the Shaefer method described in this article. The position is shown in the picture above. The scout in the bathing suit is giving the patient artificial respiration. He presses down on the patient's back at a point on a line with the lowest ribs, to force the patient to exhale, and then he releases the pressure to allow air to enter the lungs. The patient is wrapped in a blanket to prevent shock, and the scout at the left is carefully checking the patient's pulse.

arm extended above his head, the other bent and placed beneath his cheek. Turn his face to one side, of course, to permit breathing. Now kneel astride his hips, with your face toward his head and your hands on the lower ribs at the small of his back; stretch your fingers parallel with the ribs. Keep your arms straight and swing forward—though not too hard—so that the weight of your body falls on your arms and gradually forces the air out of the patient's lungs. Then swing back, releasing the pressure suddenly, so that fresh air may be drawn into the patient's lungs. It is important to release the pressure suddenly. Repeat this process from twelve to fifteen times a minute until the patient can breathe again without your help. You may need to keep it up for many hours.

Never Give Up!

Any tight clothing should be loosened. If you have a helper, let him do this while you are giving the artificial respiration. After the patient begins to breathe again, rub his limbs toward his heart. Then keep him warm in bed and see that he has plenty of fresh air. Never give up! People have been saved from drowning long, long after they seemed to be quite dead.

If a Person Is Smothering

Asphyxiation. Asphyxiation (ăs-fĭk'sĭ-ā'-shŭn) is smothering. Sometimes the smothering comes from the presence of some poisonous gas. It is treated, like drowning, by artificial respiration. First of all move the patient to some place where he can get plenty of fresh air; but do not take him into air that is too cold, or he may die of shock. Before entering a gas-filled room to rescue your patient, cover your own mouth and nostrils with a wet handkerchief. Then get him out as fast as you can, and hold your own breath until you are in fresh air again.

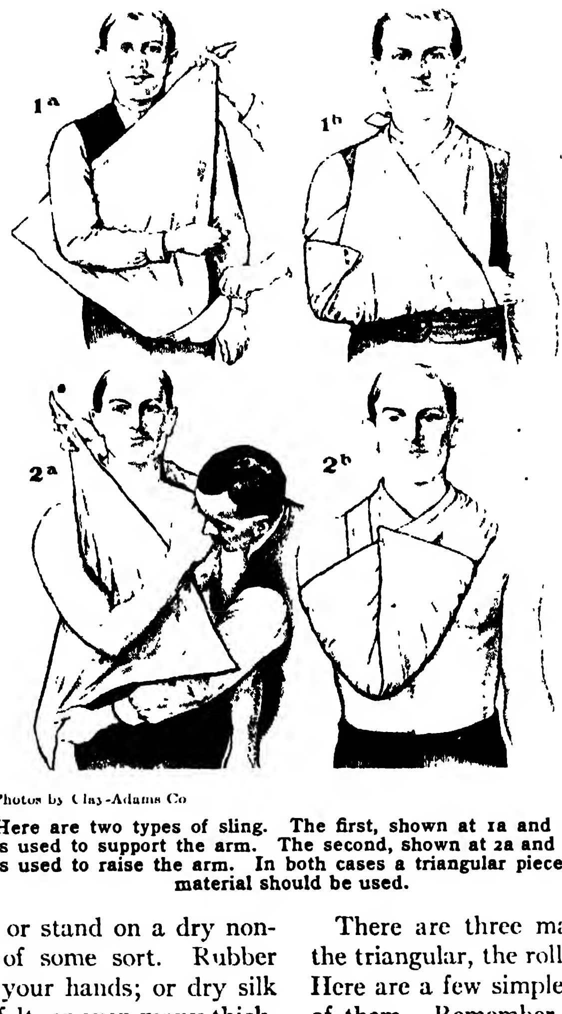
Electric shock. Anyone knows what a little electric shock feels like as it comes from a simple electric fixture. But if a person comes in contact with wire that is highly charged, the shock and burning that result may be very serious, even fatal. And often a person

who has touched such a wire cannot get free from it, because the shock causes him to lose control of his body.

So the first aider must often begin by getting the victim away from the live wire. That sounds easy, but is really a delicate matter. For if you simply take hold of the victim, the current will run right through your own body, and you will merely share his fate. You must therefore insulate yourself—that is, get in contact with some non-conductor which will break the current. Sometimes the wire may be flipped off the victim with a dry stick, or cut by an instrument with a wooden handle—the dryness and the wood insulate you. Or perhaps you can short-circuit the current by dropping a metal object on the wire between the victim and the source of the current. If you have to touch the victim himself, you must either insulate your hands or stand on a dry non-conducting surface of some sort. Rubber gloves will insulate your hands; or dry silk will do, dry wool or felt, or even many thicknesses of dry newspaper wrapped around the hands. Or you can stand on a rubber mat, a piece of glass, a glass or porcelain plate or bowl, or even a thoroughly dry board. You will notice how important *dryness* is in everything here. That is because water is a good conductor for the current.

Once the patient is free from the wire, give him artificial respiration if he has lost consciousness. Call a doctor. Treat his burns as you would treat burns of any other kind.

Bandages and how to make them. The first aider so often needs to know about bandages that something ought to be said as to how to make and manage them. Besides, you may have to use them even in the later stages of an injury, after the doctor has come and gone.



Photos by Clay-Adams Co

Here are two types of sling. The first, shown at 1a and 1b, is used to support the arm. The second, shown at 2a and 2b, is used to raise the arm. In both cases a triangular piece of material should be used.

The first general rule is this: Never, if you can possibly help it, put on an open wound any bandage—or anything else—which is not clean and sterile. A thing is sterile when it has been treated in such a way that it carries no harmful bacteria. At home or in camp, you should always have sterile gauze at hand. But in an emergency clean strips of muslin, sheets, or other white cloths, may be used. If there is time, you may sterilize them by boiling, but they must not be used wet.

There are three main types of bandage: the triangular, the roller, and the four-tailed. Here are a few simple directions about each of them. Remember that it is often necessary to lay a sterile pad over the wound before applying the bandage.

The triangular bandage. This bandage is perhaps the easiest to make and the most generally useful. Take a piece of muslin or any other strong white cloth about a yard square, and fold it diagonally. Then cut along the fold to make two bandages. Each is now ready to adjust to the injured part—

head, throat, hand, arm, chest, foot, or leg. Sometimes you will use it just as it is, unfolded. Oftener perhaps, you will need to fold it into a strip, in which shape it is called a cravat bandage. The fold is made by bringing the point of the triangle to the center of the opposite side and then folding evenly and firmly to the width you want.

In placing the bandage over the injured part, be sure to keep it smooth. Tie it with a square knot that will not slip. This bandage also makes a good arm sling or tourniquet.

The four-tailed bandage. This bandage is used for head wounds. Take a piece of cloth a yard or so long and some six or eight inches wide. Split each end into two equal parts, leaving only enough uncut at the center to cover the dressing on the wound. Then apply the bandage, crossing and tying the split ends about the head.

The roller bandage. Roller bandages are long strips of cloth or gauze rolled into a coil for convenience in handling. They are of several kinds and sizes, to fit the part of the body which has to be dressed. You can buy them already rolled.

To apply this bandage, place the outside of the roll next to the part to be bandaged, hold the roll in the right hand, and unroll it gradually and carefully as you wrap. To start wrapping, take hold of the loose end with the left hand, and make the bandage secure by wrapping several times around the same place. As you wrap, unroll the bandage a little at a time, and keep the pressure against the body uniform with each turn. Otherwise the bandage is not likely to stay on, and it may even interfere with the patient's circulation. Sometimes turning the bandage over occasionally where it is wrapped around a body curve will help keep it snug. This sort of bandage is especially effective for a sprained ankle or wrist.

No bandage should ever be put on too tightly. If you put it on shortly after an injury, remember that the injured part will probably swell. If a bandage seems to be too tight, it should be loosened at once. After the swelling has gone down in a sprained wrist or ankle, however, a roller bandage may be put on pretty snugly to provide support.

In bandaging, always start at the bottom of the area to be covered and work upward. Bandage the injured part in the position in which it will remain when the dressing is completed. For instance, if an arm is to be carried in a sling bandage, do the work with the arm in the position in which the sling is going to hold it.

One more rule: Never, under any circumstances, apply a wet bandage.

These are all things which a good first aider knows. We should all know them—and a great deal more. The best way to learn more, and to grow skillful, is to take lessons in some such organization as the Boy Scouts or the Girl Scouts. Anyone needs a good deal of practice before he can become expert, but everyone ought to learn, nevertheless. For no one knows at what moment a life may depend on his knowledge as to how to give first aid.

When your pet comes limping to you with a cruel thorn or a nasty cut in his paw, do you know what to do about it? Sometimes a small wound will heal more quickly if you merely wash it clean and let Rover finish up the treatment himself.

If a bone is broken, your pet should be taken at once to a veterinary. If that is impossible you must improvise a splint yourself; otherwise the bones will knit together in a wrong position, and the animal will have a crippled limb for life.

Photo by Boy Sc

HOW *to be* HEALTHY

Reading Unit No. 2

HOW TO BE HEALTHY AND STRONG

Note: For basic information not found on this page, consult the general Index, Vol 15.

For statistical and current facts, consult the Richards Year Book Index.

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Things to Think About

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Why is worry an enemy of health?

How can you avoid toothaches?

Why do dirty hands spoil clean food?

Picture Hunt

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Summary Statement

In order to be healthy a person must follow certain rules of health, but not worry about them.

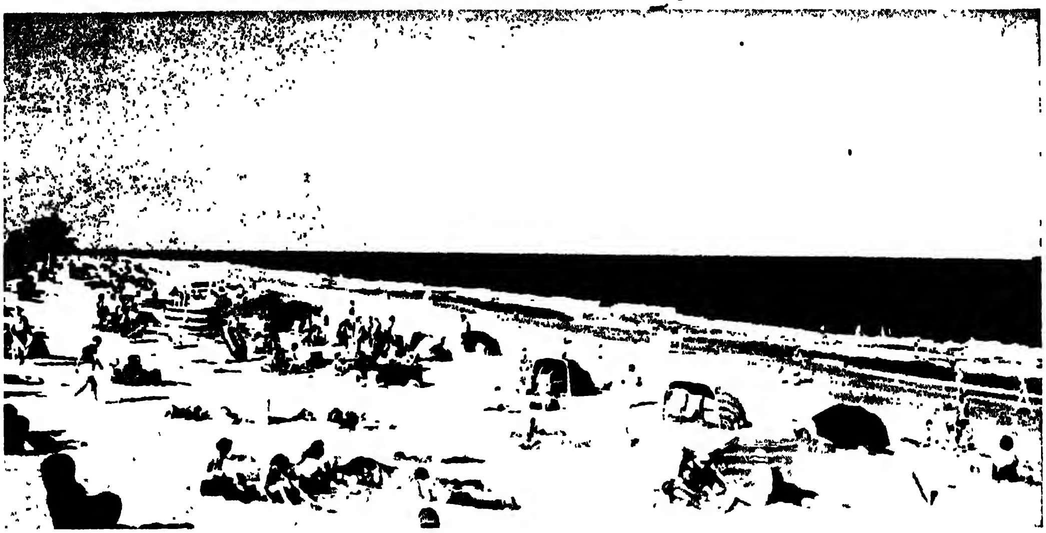


Photo by Florida East Coast Ry

This is fun! And it is a place for exercise, too. Everyone loves to splash about, and for swimmers a sea beach or a lake or stream offers rare sport. But best of all, perhaps, is the sun bath that should follow your dip. Let it be brief at the opening of the season, for sunburn can be dangerous as well as painful. When you get a good coat of tan you can stretch out on the beach or bank for as long as you like.

HOW *to* BE HEALTHY *and* STRONG

Anybody Who Will Do the Few Simple Things That Are Listed in These Pages Ought to Find It Delightful to Be Alive

CAN you imagine anyone who would rather have a toothache than not, who really likes to be all tired-out halfway up a little hill, or who would rather be sick in bed than playing outdoors with the "gang"? No, there is nobody who ever wants to be weak or ill. And yet most of us are often doing things that are likely to make us sick either now or later, or leaving undone easy little things that might help make us strong and well.

Of course some of us have healthier bodies at the start than others. And there is hardly any more inspiring tale of heroism than one that tells of someone—like Robert Louis Stevenson, for example—who has been useful and happy in spite of being always sick and in pain. But it is so much easier to be useful and happy when one is well and strong! We shall get along much better if we can be like Demosthenes (dē-mŏs'thē-nēz), the great orator, who cured himself of a stammer and made a great voice out of a little one by shouting against the waves—or like Theodore Roosevelt, who was puny and sickly as a child and yet trained himself to be an orator and a soldier and the most strenuous man in his generation. Most of us can be well if we are willing to try hard enough.

Here are nine simple rules:

1. Hold yourself straight.
2. Take enough exercise.
3. Get enough sleep.
4. Breathe fresh air.
5. Bathe in the sunshine.
6. Wear sensible clothes.
7. Eat sensible food.
8. Drink plenty of water.
9. Keep clean.

If you will read what follows carefully, you will see why all these rules are important, and how you can follow them.

Rule 1. Hold yourself straight. In the first place, a person who slouches along the street or sits humped over in a chair is not at all good to look at. It is the straight, graceful, athletic person whom we all admire. Besides,

the person who slouches and grows round-shouldered, does not leave room for his lungs and other organs to expand as they should. So if there is any pneumonia or similar disease about, it is more likely to find him an easy victim than if he were a straight-shouldered person.

Can You Stand Like a Pine Tree?

Learning to stand straight is a matter of training the muscles—and that means keeping everlastingly at it! If you do not do it when you are young, it will be almost impossible to do it later, when your muscles have hardened in the wrong places. Practice "standing like a pine tree." If you are not sure just how a pine tree stands—that is, just how you can best imitate its tall and lovely straightness—get one of your friends to give you this test. Let him take a string, hold one end of it against the front of your ear, and see where the other end falls. If you are standing properly, it should fall against the front half of your foot. To make it fall there, your shoulder blades should be flat, your feet pointing straight forward, your knees straight, and your head held high. Now take a deep breath and feel the good air in your lungs! And for the rest of your life, remember to walk as if you had a crown on your head and a star on your chest.

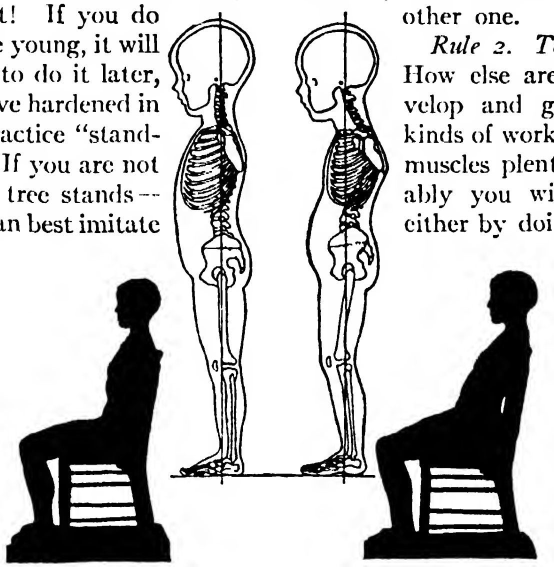


Photo by U. S. Dept. of Labor

Which are you—the flat-chested, pot-bellied, spineless-looking individual at the right, or the strong, upstanding, capable-looking person at the left? Good posture, whether in standing or in sitting, is just as important to health as cleanliness is. Keep your head up and your chin in. Throw your weight forward on the balls of the feet. Your chest should project further than any other part of your body. But that does not mean that you should try to imitate a pouter pigeon! Do not raise your shoulders and push them back as far as you can get them. Let your arms hang down normally in a relaxed position and forget about your shoulders. For the key to good posture lies in the way you hold the lower part of your body. Hold your stomach in, making the distance between the front and back of your hips as narrow as possible. If you do that and follow the other instructions given here, your shoulders will take care of themselves.

As you walk like that, point your toes straight forward. If you turn them out, you put the weight on the wrong muscles and throw the foot out of balance. Indians always walk with their toes straight ahead. Shift your books or bundles from one arm to the other, so as not to hump up one shoulder by always crooking the same arm around what you are carrying.

When you sit, your lungs need as much air as they do when you stand. So practice keeping your head, neck, and body in a straight line. The body should bend only at the knees and the waist. If your desk at school is so large or so small that you cannot comfortably sit in this way, tell your teacher about it, and doubtless you can have another one.

Rule 2. Take enough exercise. How else are the muscles to develop and grow strong? Some kinds of work, of course, give your muscles plenty to do. But probably you will get your exercise either by doing gymnastics or by playing games. Perhaps there is a gymnasium at your school, or somewhere else not far away, and there you will find all sorts of fascinating ways to develop muscle—dumb-bells and bars and swinging rings and all the rest. Or perhaps you have setting-up exercises in school, or can do them with the help of directions over the radio at home. Certainly someone—your teacher perhaps—will help you out if you want to take your exercise that way.

But you will probably find it more fun, at least part of the time, to play games. A few of these, such as basket ball, will keep you indoors, but most of them will take you outdoors the minute it stops raining. Skating and rowing and swimming, football and baseball, tennis, taking long walks—as well as skipping rope and playing tag and all the other old favorites from blindman's buff to

Fig. 1. Start with arms at sides, palms in. Raise arms sideways to vertical position, then down again. Heels should be together and lower part of body held rigid. Fig. 2. Same as Fig. 1 except that arms are swung forward instead of sideways.

Don't overdo! A few rounds of exercises will do for a beginning, and you can work into more later on. Always keep your windows wide open while doing your "daily dozen" --or better still, do them out of doors in the open air and sunshine.

Fig. 3. Arms at side and horizontal. Swing in circles, as dotted lines show you.

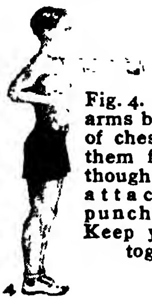


Fig. 4. Hold forearms bent at side of chest. Thrust them forward as though you were attacking a punching bag. Keep your heels together.

Fig. 5. Forearms bent and in horizontal position, elbows forward, fingers on shoulders. Swing from front to sides and back again.

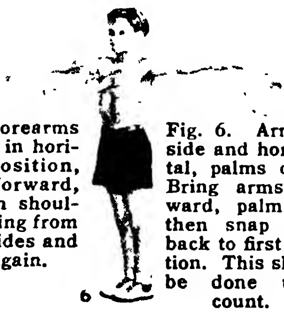


Fig. 6. Arms at side and horizontal, palms down. Bring arms forward, palms in; then snap them back to first position. This should be done to a count.

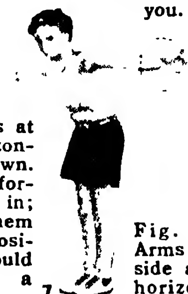


Fig. 7. Arms at side and horizontal, body bent slightly forward. Circle arms backward.

Fig. 8. You may not be able to do this at first. Keep feet together and knees straight. Raise arms to vertical position. Then, without bending knees, touch the floor— if possible! Fig. 9. Hands on hips. Bend forward, keeping head up and knees straight.

Fig. 10. Hands on hips. Bend to the side - first to one side and then to the other—without moving lower portion of the body. Fig. 11. Arms as in Fig. 6. Swing arms downward, forward, and backward, rising on toes at end of backward swing.

Fig. 12. Hands on hips; feet apart. Swing upper part of body from the waist, describing a semicircle. Fig. 13. Hands on hips, body straight. Rise on toes.

You may do these exercises at any time of day except directly after meals. Before breakfast is a fine time. It is well to count as you do them all.

Fig. 14. Stand as in Fig. 10. Rise on toes as in Fig. 13 before you come to rest with your knees doubled under you.

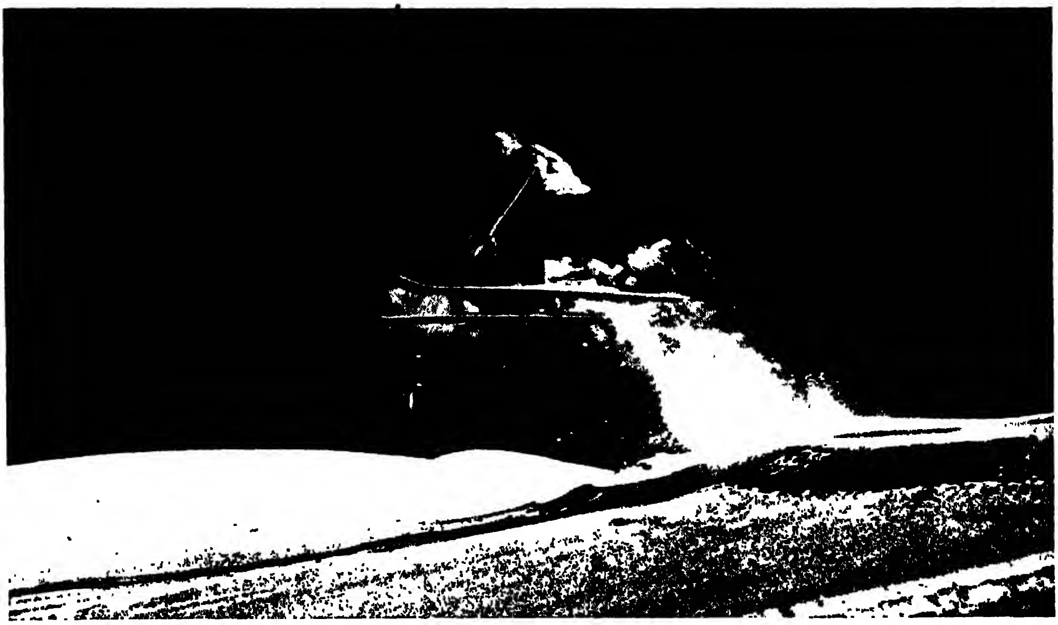


Photo courtesy of Canadian Information Service

The summer sun can give us vitamin D, but winter too can offer us health in its bracing air and vigorous exercise. One of its most exciting sports is shown in our picture of a Canadian skier in Garibaldi Park, near Vancouver. Canadians hold impressive records in skiing, as do various other peoples of the North. In Norway it is the national sport. But you need not be an expert to get fun from this healthful diversion.

hide-and-seek—all these there are, and a hundred more. Every boy or girl should be able to do at least one of these things well.

But that does not mean that you should try to be *too* strenuous. It never does any good to get too tired; and we must all take time to grow brains as well as muscles. Do not spoil the fine glow of healthful exercise by carrying the thing too far. If a girl keeps skipping rope too long, her heart may suddenly fail her under the strain. If a boy plays baseball too long and hard, he may wear himself out so that he cannot play again for a long time. And it is always a bad plan to exercise violently just after a meal—it upsets your digestion.

Rule Number Three

Rule 3. Get enough sleep. Of course it is very hard to have to tear yourself away from an exciting book to go to bed, but after all, the book will still be there to-morrow. And if you do not get enough sleep, you will be sleepy and sluggish to-morrow; you will wonder what makes the mathematics so much harder than usual, and be disgusted at yourself for being always "it" in the running games. The truth will be that the machine that is your body is half run down—it needed more time to be refueled and repaired during the night. If that sort of thing keeps up, you will never be so well and strong as you ought to be.

How Long Should We Sleep?

Just how much sleep you need depends on your age and your general state of health. Little babies, of course, sleep most of the time. Grown people, if they are healthy, usually need about eight hours every night. Children need more, for they use up more energy growing. At ten you should have ten or eleven hours. A cat nap during the day is an excellent thing, too. Or if you cannot take a nap, just fifteen minutes flat on your back with every muscle relaxed will do wonders. Try it the next time you go on a long hike. You will be surprised how it will refresh you. The best time for a nap is just before dinner.

Rule 4. Breathe fresh air. One of the simplest ways for us to get fresh air is merely

to breathe it in as we sleep. For then we always throw the window wide, no matter what the weather. We sleep much better so, and our bodies have more chance to build themselves up again. During the day, it is good to spend as much time as we can out of doors, in fine weather. Much of our play will be in the open air, and often we can even study or read or talk or eat out of doors. When we have to stay in, we can usually leave the window a little open. You will see how important all this is when you learn that many schools are kept entirely out of doors, even when the pupils have to bundle themselves up in warm clothes. The main medicine given for tuberculosis nowadays is plenty of fresh air.

The Magic of a Sun Bath

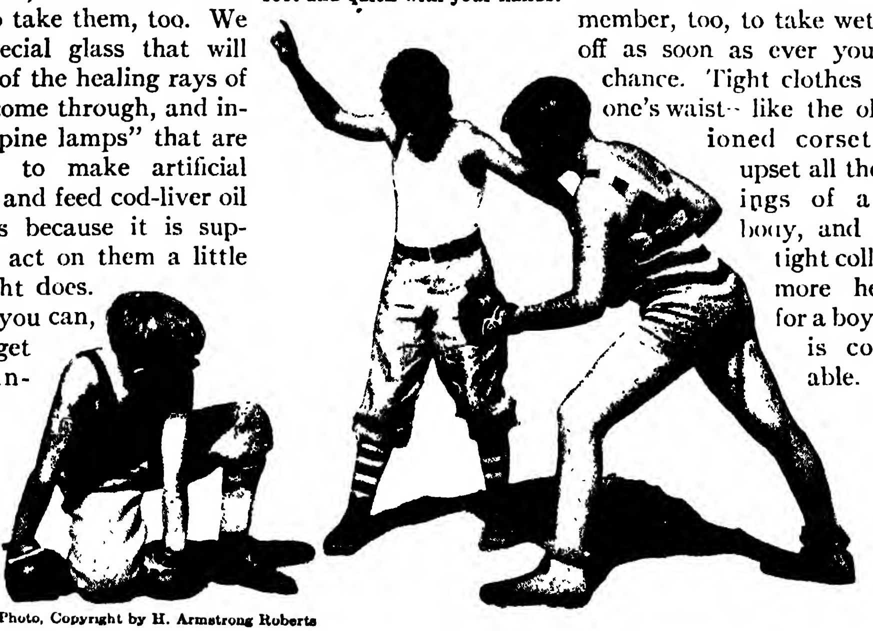
Rule 5. Bathe in the sunshine. Have you ever seen potatoes that have lain in a dark cellar all winter and have long sprouts on them, with sickly little leaves? How pale and sick-looking the plants are! It is because they have never had any sunshine. Just so, without sunshine, you and I would get pale and sick, and finally would die.

It is only recently that we have fully realized this. Now we send sick people to take "sun baths," and advise well people to take them, too. We make special glass that will let most of the healing rays of the sun come through, and invent "Alpine lamps" that are supposed to make artificial sunlight, and feed cod-liver oil to babies because it is supposed to act on them a little as sunlight does.

But if you can, you will get your sunlight straight from nature. You will sit or play out of doors on sunny days. You will let the sunshine stream through your windows—remembering that if the weather is not too cold, it is better to throw them open, for not all the sunshine can come through ordinary glass. You will lie and bask in the sun in the cool grass or on the beach, if you get a chance. Only, if you are going to take sun baths or put on a deep shade of tan, do not go about it too fast. Sunshine burns, and you may find yourself in bed with a painful set of burns if you are not careful. Start with a very little bath—three minutes, say Next time you can cook yourself longer, time after next longer yet. After a while, you will be able to stand a good deal of the sunshine at once.

Rule 6. Wear sensible clothes. While you are sun bathing, the fewer clothes you can decently wear, the better. Of course we cannot always go around in a bathing suit, much less in no clothes at all. Yet we can usually wear healthful and sensible clothes, and they need not be any less attractive for that, either. If you do not like to have colds—and who does?- you should not insist on running around on a cold day without an overcoat, or going out in the rain without rubbers. You will remember, too, to take wet things off as soon as ever you get a chance. Tight clothes around one's waist-- like the old-fashioned corsets—can upset all the workings of a girl's body, and a stiff, tight collar is no more healthful for a boy than it is comfortable. As for

He's not out by any means! He is a wise boy, and before the count of ten he'll be up, stronger than ever for having rested a minute. Boxing is great sport. It makes you steady on your feet and quick with your hands.



Photo, Copyright by H. Armstrong Roberts

the high, spike-heeled shoes some girls think it smart to wear, they give one an awkward carriage, throw the balance of the foot all askew, and cause corns and bunions and other pains to spoil one's disposition. If the girls knew how silly and awkward they looked tottering along on them, they would never be willing to wear them again!

All clothing should be loose enough, light enough, warm enough, and porous enough. It should be loose and light enough to let you be comfortable and to let your blood flow freely. It should be porous enough to let plenty of air reach your body. And it should be warm enough to keep you from taking cold. The moment you start to perspire inside a house, you may be sure that either your clothes are too heavy or the room is too warm.

Rule 7. Eat sensible food. The first thing to remember about food is that we need just the right amount of it—neither too much nor too little. The reason for this is plain: our bodies are all the time using up energy and the very stuff they are made of, and if we do not give them more fuel to be burned up in energy and more material to rebuild themselves, they will soon get weak and dwindle away. On the other hand, if we greedily stuff ourselves, the body will have too much work to do trying to turn all the fuel into energy and body tissue, and we are likely to be ill. This means in practice that we ought not to take a second piece of pie when we honestly feel pretty full with the first one. It also means that we ought not to go without dinner because we are too busy to eat it. And if a girl is tempted to starve herself for the sake of a fashionably slim figure, she ought to stop and think whether a weak and sickly young woman, all too likely to have tuberculosis, is going to be very attractive—to say nothing of useful or happy—for all her slimness.

Photo, Copyright by H. Armstrong Roberts

All lathered up! This boy knows that to be clean is to protect himself from disease germs, as well as to make him a pleasant table companion. And he finds that with plenty of soap and splashing, washing up can even be great fun!

The second thing about food is that we need it at regular hours, so as not to keep our stomachs working all the time, or starved and overworked by turns. Here is another reason for always stopping study or play at mealtime, and a very good reason for not eating between meals.

The third thing to remember is that we need the right kind of food. Experts have very cleverly worked out just what foods we need, and have told us all about "balanced diets." We should eat simply, and not ask our stomachs to digest too much heavy, greasy food, such as fried things, or too much very rich, sugary food, such as candy and pastries. We should not eat too much meat; once a day is quite often enough for most people to eat meat. Tea and coffee are mainly good as stimulants—that is, to make a person feel more full of energy. Children usually do not need or even like these drinks, and are much better off without them. Even grown people would usually be better off without quite so much of them. Tobacco and alcohol are always harmful.

On the other hand, unless you are different from most people, fruits and vegetables—especially fresh fruits and vegetables—will be very good for you. Lettuce and other uncooked vegetables are considered especially healthful. Milk is good for people. Every young person should take a quart and every grown person a pint a day. Coarse food such as brown bread and certain cereals, give us "roughage," and eating them will help in regular digestion.

Photo courtesy Du Pont Magazine

These boys waiting to take a plunge in the old swimming hole know that having good health means having fun. Poison from those shiny, three-leaved ivy plants hanging over their pool causes a severe itch and could ruin their summer play. So they are staying out of the water until the ivy is killed by this spray.

Rule 8. Drink plenty of water. Did you know that your body is nearly three-quarters water? Solid as it looks and feels, it is three-quarters liquid just the same. And every day much of this water is given off, through the skin and lungs and kidneys. So it is not hard to see why we ought to take in a plentiful new supply. There is a good deal of water in our food, of course, but it is not enough. At least six glasses extra are needed. You may get thirsty often enough to drink that much, but it is a good idea to keep track. You might try taking a glass before breakfast, two between breakfast and lunch, two between lunch and dinner, and the last just before you go to bed. If you drink water with your meals, be careful not to wash them down with it—that is to say, chew the solid food and do not drink until you have swallowed it.

The Most Important Rule for Health

Rule 9. Keep clean. This is perhaps the most important rule of all. It is important, first, that the things we take inside us should be clean—our food and whatever liquid we drink. If the water in your town is not pure, it should be boiled before it is drunk. It is not a good idea to drink out of the same cup or glass with other people, even in your own family. That is why drinking fountains or paper cups are now used in most schools and other public places.

Our Invisible Enemies

The reason for being careful about these things, and indeed the reason for nearly all cleanliness from the point of view of health, has to do with germs. You probably know that most diseases are carried about by little living things, so tiny that they can be seen only under a microscope, and that these little germs get into our bodies from all sorts of things we eat or drink or handle. Of course we might as well have a disease as spend *all* our time and energy trying to avoid it; but the most important precautions are really very little trouble, and it is merely a matter of knowing what they are. Besides, being clean is, just in itself, one of the pleasant things in life.

Of course, food may be as clean and pure as you please when it is put on the table, and yet go into your stomach covered with bacteria. For if your hands are dirty when you put it in your mouth, what else can happen? That is one of the very good reasons for always scrubbing your hands well before you eat. Indeed, one ought not to handle food at any time with dirty hands. Unless hands have a good reason for being dirty—when we are working in the garden or playing baseball, perhaps—they are always much better clean. Have your own towel in the bathroom, just as you have your own toothbrush. And remember that hands are not clean when there is a black line of dirt under the nails. A nailbrush vigorously used will do wonders in "sprucing you up" for dinner.

We do not wash the rest of our bodies so often as we wash our hands, for the rest of us is not likely to get so dirty. But we need a bath certainly as often as twice a week and probably every day. And in between we need to scrub our faces and our necks and ears. As to the bath, if you like steamy hot ones, you had better take them at night just before you get into bed. If you take a hot bath in the morning, it is just as well to end it with a cool shower or rubdown. Nothing can make us feel so refreshed and contented as a fine bath.

How to Avoid the Dentist's Drill

We have to be especially careful to keep our teeth clean, for bits of food are likely to stick between them or a film to form on them. They are not only very ugly when they are dirty, but may decay and give us toothache besides. A clean toothbrush, not too soft, that has been aired well and if possible hung in the sun, is our best weapon against toothache and all such ills. That is, of course, if we use it! We should use it every morning and every night, vigorously and well, with an up-and-down motion and on all the surfaces of the teeth. About twice a year we ought to let a dentist look our teeth over, whether we have been having any trouble or not; he may be able to keep us from having it.

How often you should wash your hair will depend on how dirty you get it, and also, somewhat, on how long it is. A boy or girl with short hair, who plays out of doors a good deal, may need to wash it nearly every day to keep it clean. Long hair is harder to wash, of course, and also it takes so long to dry that you have to be careful not to catch cold while it is drying. Ordinarily, if you wash your hair, say, every two or three weeks, and brush it every day, that will do very well. Use a pure, fine soap or shampoo, and be sure to rinse it all out. Two or three soapings and four or more rinsings are usually necessary. Make each rinsing water cooler than the last, ending with cold water—just as you take a cool shower at the end of a warm bath. Between shampoos, brush and air the hair well, and frequently wash the brush and comb. A little ammonia in the water will clean the brush and comb like magic; they should then be dried in the sun.

The Best Rule of Health: Be Happy

Now, if you have taken all these pains to keep your body clean, you will naturally not want to put dirty clothes on it, or have other dirty things around. You will shake your clothes out at night to air instead of throwing them in a heap on the floor. Things that cannot easily be washed you will sometimes hang in the cleansing sunshine. And though—let us hope!—you will not suddenly become afraid of digging in the dirt or eating apples off the trees on occasion, you will get into the habit of liking to be clean. It is one of the pleasures of life.

So here are our nine simple rules. They *are* simple, are they not? If you follow them, the chances are that you will be a great deal healthier and happier than you will be if you do not. Do not worry about them, but just follow them because you like them. For the tenth and last rule—and the most important yet—is *Do not worry!*

Reading Unit No. 3

CONSERVING HUMAN LIFE

Note: For basic information not found on this page, consult the general Index, Vol. 15.

For statistical and current facts, consult the Richards Year Book Index.

Interesting Facts Explained

Things to Think About

Why do more young people than old die of accidents?
What does the safety engineer do?
Why are there more accidents in the home than on the street?
What should you do when a little child is foolhardy?
What causes accidents in elevators?
How can we stop traffic accidents?
What makes a highway safe?

Related Material

Summary Statement

Without being afraid, we should do everything possible to avoid danger and to meet it intelligently. Conserving human life means looking out for others as well as for ourselves. Good habits, formed in childhood, are the best insurance against accidents. The dangers of modern civilization can be met only by intelligent training and coöperation. Highways should be safe and automobiles tested for safety. Drivers must be trained and disciplined. Accidents are cut down by various associations. Everyone should spread the gospel of good habits.

Photo by J. C. Allen & Son

There will be no traffic accident here. The boy patrols are attending to that. The red flag will hold up approaching motors until the last child has crossed the street. But what will happen when no one is near to stand on guard? Have these young people been taught to look out for themselves? Have they formed the Good Habits that will be as valuable as the magic talisman of the fairy tale in protecting them from danger? Not long ago experts told us that, by the law of averages, seven or eight of these twenty-three young persons would sometime be seriously injured in a motor accident. The fifteen or sixteen who escape will probably be those who have formed Good Habits. Are you one of them?

CONSERVING HUMAN LIFE

Some Hints as to How to Face Danger and How to Save Yourself and Others from the Many Disasters That Threaten Us at Home and in the Street

ONE of man's worst enemies is fear. It causes war among nations and bitterness among groups. It is at the root of much of the world's cruelty and deceit. And if as individuals we fall prey to it, we are likely to find that it has lowered our efficiency, thwarted our happiness, and even impaired our health.

Now what are we to do about this great shadow that darkens all lives at times and turns others into perpetual night? Clearly there are going to be moments when danger threatens. Are we going to shut our eyes to it and act as if nothing were there? By no means. That would bring certain disaster. But we shall surely take all possible steps to avoid or reduce the danger. Then, and only then, shall we be able to go through life chin up and eyes straight ahead.

For as you must have noticed, it is the over-timid person who is always getting into trouble. He sees danger on every hand. Many of his fears are of course imaginary. But he is so busy worrying about them that he never takes the time to look at them calmly and find out just how grave they are. And he is always in such a panic that he never can decide wisely as to what is the best thing to do. So disaster constantly befalls him. He is as childish about danger as the foolhardy person. Both will come to grief, for neither one is truly brave.

Now there are few things that the world admires more than bravery. This is partly because your really brave man is likely to be successful. He sees the dangers, he knows what they are worth, and he takes wise steps to counteract them. A foolhardy man, on the other hand, usually reaps nothing but contempt. He has too little sense to see the situation as it really is, and so trusts to luck—about the silliest thing a man can do. For

in trusting to luck there is just one thing you can be certain of—that some day it will fail you!

How to Face Danger

Of course fears are of a thousand different kinds, and affect people in different ways. But no matter whether a man dreads poverty or failure, disgrace or disease or death, he cannot suffer from a fear that does not lose some of its terrors when he looks it calmly in the face and resolves that no matter what comes he will play a man's part. If he can do that he has usually gone a long way toward overcoming the danger. And if, in addition to this, he can take intelligent steps to avoid the danger or to meet it successfully, he can feel fairly safe. We are going to talk here about some of those steps—what they are and how we may go about taking them. If our directions are followed, life will be robbed of many of its fears and even more of its dangers.

The Enemies of Early Man

Early man probably feared nothing so much as the great forces of nature. Storm and flood, famine and pestilence and the attacks of wild beasts were a constant threat. To-day we can control all those dangers with fair success, and the average length of human life is much longer than it used to be.

But our very progress has let loose a new set of perils that grow more threatening every day. They take a fearful toll of young and old, of life and health and usefulness. The number of those needlessly injured, maimed, or killed every year is appalling. Often it is greater than the whole list of killed and wounded in the course of a long war. Between the ages of three and eighteen more people die of accidents than of all the diseases put together. And among people of all ages there are only three diseases that cause more deaths than are caused by accidents. When one remembers how many elderly people die of disease, these statistics become very impressive. They become more tragic still when we remember that such deaths are largely preventable!

Now what are we going to do about it? Surely something more than shake our heads and say it is too bad! Unless man is intelligent enough to learn to control the modern conditions which he has brought about, he had better go back to savagery. It would be safer!

On other pages we have told of the hard fight intelligent people are making to protect our wild animals from the cruelty of merciless and greedy men. Certain kinds of beautiful wild creatures, such as the passenger pigeon, have been completely wiped out. To-day we see them only in pictures or perhaps stuffed in museums. Their own instincts had been enough to protect them against such enemies as they would naturally meet in forest and field and stream, but the sudden appearance of thousands of death-dealing guns in the hands of thoughtless hunters was something they could not cope with. They fell by the hundreds of thousands. And more than that, they were robbed of their natural homes and breeding places when hundreds of square miles of wild marsh land were turned into reservoirs or fields by clever engineers. What were they to do? They were at the mercy of man—and man seemed to be merciless!

Can We Survive Our Own Machines?

Now we have gradually awakened to the stupidity of wiping out the lower creatures that are so useful to us. All sorts of steps are being taken to save their lives—or, as we say, to "conserve" them. *But what about the conservation of human life?* Man too is beset by countless physical dangers that instinct cannot save him from. He is better off than the lower animals, for he has reason to help him solve the new problems, which his forebears never had to meet. But unless he is willing to follow reason—and a good many people do not seem to be—men will go on dying at a terrible rate because they cannot control the machines that their own hands have built. Unless every one of us learns to prevent accidents, both for himself and for other people, we shall certainly be bringing disaster, or even death, to some innocent person—it may be to the one we love best in all the world.

The chief victims of accidents are children

and industrial workers. It was with the coming of the machines that toil became so dangerous. The setting up of factories at the close of the eighteenth century and the beginning of the nineteenth, put thousands of people into dangerous jobs which they worked at for long hours every day under conditions of great strain. Nothing was done for their protection. If they got hurt the employer shrugged his shoulders, said they'd been careless, and left them to suffer or die.

Finally the more humane employers began to take steps to protect their workers from undue hazards; and at last the government stepped in with laws compelling such protection and supervising conditions of labor. Providing safety for its people has now become one of the chief concerns of our government.

Moreover, the employers have come to realize that workers who know they are safe will do better work. In 1912 the heads of various great industries organized an association which we call the National Saety Council. It uses every means in its power to educate the public to cooperate for the greater happiness and safety of everyone in our land. In the factories safety is now one of the first considerations. Workers are provided with machines as safe as the inventor can devise. They are trained in the practice of safety, and are even penalized for failing to observe safety regulations. And they are rewarded for any suggestions they may make for promoting their own and others' safety. The Council publishes facts concerning all accidents in the entire United States. It classifies accidents as to type, cause, season, and other factors, so that there may be a sound scientific basis for building safety programs. The insurance companies publish their own findings.

Photo by J. C. Allen & Son

Baby has a burn not a bad one, but painful enough, as all burns are. And Baby's mother is sorry, as one may see from her grave expression. But she is relieved also, for it might have been much worse, and she knows that now he will never put his hand on the hot stove again. No amount of talk could have been so effective as this one bit of painful experience.

Meanwhile hazards have grown so numerous and so technical that a lifetime is needed to understand those in a single field of industry. Ou millions of machines, our delicate electrical devices, our rushing railway trains and darting automobiles have converted safety into a science. As a result we have a brand-new calling. It is the profession of the safety engineer, a specialist who studies safety from every possible angle. Nearly every large industrial plant hires such a skilled scientist to study its machinery, devise ways of teaching safety to the workers, and plan regulations that will help its employees to take as few risks as possible. For smaller plants the safety engineer may be called in, just as a doctor, a lawyer, or an architect is.

As a result up-to-date factories are clean,

well ventilated, and well lighted—safety has been built right into the structure! And out of the new demands a whole industry has grown up. Its business is the manufacture of safety machinery and appliances. One company makes nothing but mine equipment—safety lamps, belts, goggles, and similar devices for the use of the workers themselves, and air-conditioning, gas-detecting, and alarm systems for the operation of the mine.

What Is "Scientific Management"?

When our large industries introduced what is known as "scientific management" they took another great stride in the conservation of human life. Under scientific management an "efficiency engineer" makes an exhaustive study of a plant—of its structure, its organization, its methods of production—and then works out a plan for eliminating all waste, whether of materials or effort. He decides just what is the most efficient way to operate every machine and to do every job that the factory requires. Every motion of every worker is analyzed, and the workman is taught just how to work with the least effort and greatest speed. For that is what "efficiency" is. It must aim to save people from weariness as well as to increase speed and accuracy. It aims to find out the best possible way to do things.

Now it is easy to see that the best way of working must of course be the safest way. A blundering, clumsy workman is not only likely to botch his work; he will probably cut his hand or break his leg or meet with a still graver accident. When all the men in a factory have been trained till it is second nature to them to do everything in the safest and most efficient way, that factory will have many fewer accidents. Training the worker in safe habits has replaced the older, less effective custom of putting up horrifying posters of bloody accidents in the hope that workmen would be terrified into being careful. Posters are still used to-day, but only as reminders that "Good Housekeeping in the Shop Is Essential for a Safety Record," or that it is well to "Avoid Wearing Finger Rings around Machines." The older, gruesome pictures did a certain amount of good, but careful habits accomplish much more. In 1918 deaths in industry were two and a half times as numerous as deaths from traffic. To-day your relatives and friends in mill and mine are safer at work than while driving or walking home.

How Safe Is Your Home?

Home! A haven of rest and security! No, hardly that. Strange as it may seem, the home, usually considered the safest place in the world, is the scene of a large proportion of our serious accidents and of the less serious ones as well. A third of the accidents to children occur there. Many come from falling downstairs, falling off porches or out of windows, and tumbling from ladders or chairs. Others come from slipping on floors or falling over obstacles. Burns and cuts are common at home, and injuries from electrical devices. It is usually there that poison is taken by mistake. And it is there that people, especially small children, are most likely to suffocate in bed. Most of these accidents, as you may see, come from carelessness in one way or another. In 1936 there were 37,800 deaths from traffic accidents; yet the total of those who met their death from accidents at home exceeded this figure by seven hundred!

Causes of Accidents at Home

Now home is a place where we do a great many different kinds of things, and where we very much need to look out for one another. There is no police officer there to remind us that we must stand the rake in a corner when we have finished using it, or that we must be careful in going down dark stairways. To be sure, local ordinances deal with fire prevention and provide certain housing laws necessary for safety, but most home accidents, in fact sixty-eight percent of them, are a result of personal carelessness—of poor judgment, hurry, or intoxication. It would seem that good housekeeping is necessary for safety at home as well as in the factory. Eighteen percent of home accidents are a result of disorder.

And this brings us to what is at bottom the most important factor of all in avoiding danger for ourselves and for others. It is

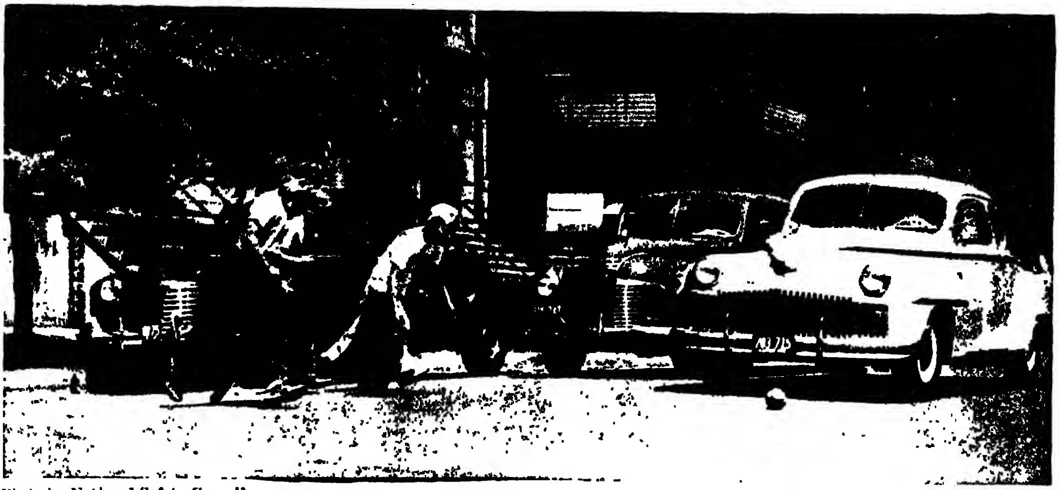


Photo by National Safety Council

These young men are sadly in need of education in safety. They may think the world revolves around their own games, but a high-powered automobile is not so easy to stop as their softball is. The chances are excellent that, unless they become "safety-minded," not all of them will grow to be men.

the magic charm of safety. With it we shall go through life securely and happily. Without it we shall be dogged by fear, disaster, and even death. What is this charm of great power? It is the formation of Good Habits.

Are You Always Getting Hurt?

Now let us see what we mean by "Good Habits" in matters of safety. You must have noticed that some of your friends are always having "bad luck." They are continually cutting themselves, skinning a knee, getting knocked off a bicycle, or running into sharp corners. Sometimes it all comes from poor eyesight of a kind that the ordinary medical examination does not reveal. Sometimes it comes from what psychologists call a "complex"; your "unlucky" friend may be so full of the fear of being hurt that he actually brings about what he fears. Both of these defects can be remedied if your friend will be examined by an expert and follow the expert's advice.

But all this does not account for the fact that some people are "just naturally safety-minded," while others are what we call "accident-prone." When scientific management was first installed in factories the nurse in the dispensary soon found that the patients treated for injury were likely to be "repeaters." Before long she was able to fill in their records without asking any questions. Those men were old acquaintances. But others in the plant she never saw at all. They were the deft and careful workmen, whose names were on the records for high production but were never registered in the medical dispensary. They knew how to do things in the most skillful and efficient way. They never miscalculated and never made mistakes. In other words, they had formed good habits in handling their work, and to do things right was second nature to them.

That is the secret of avoiding accidents wherever we go. There is a right way and a wrong way to do everything, and the right way is always the safest way, as well as the most efficient. It is the way of the successful person. This truth applies to sports and recreation as well as to work. When you learn a new sport, learn it correctly. No football coach has any use for a player who will not learn the right way to fall. He knows that a team made up of such men would be taken to the side lines with broken ribs and broken noses before the game was half over.

Do as the Expert Does

Many people do not seem to realize that the expert may have something to teach them. There is, for instance, more than sheer "nerve" to the art of diving. Your

expert demands to know the temperature and depth of the water and the kind of bottom before he goes off into a lake or river. And he first loosens his muscles with a bit of swimming. He tries simple dives. Only after he is entirely familiar with his surroundings and his own physical condition does he attempt an exhibition dive. In the same way, it is ludicrous to imagine an expert skater venturing on thin ice. He knows too much about skating to do that! No one but a greenhorn or a "smart alec" takes risks of such a kind.

The Magic Charm

Fortunately, anyone who wishes to form good habits which will help to conserve human life can begin at this very moment - no matter how careless he may have been in the past. There is nothing mysterious about the process. All that is necessary is to repeat over and over those acts that you wish to have for habits and never to allow yourself to do things in any other way. Most of the habits you will want to form will come easily enough. It is no harder to walk along a country road with your face to the oncoming traffic than it is to walk on the other side of the road and it is very much safer. A great many accidents come from the fact that people on foot walk on the right instead of the left side of a highway. Your state department of highways can tell you just how many persons have been killed in this way during the past year in the state in which you live.

In the same way, it is actually much easier to cross a crowded street or highway when the traffic light is green than it is to cross through the stream of traffic. And how much safer! If you live in a large city you may find it interesting to ask police headquarters just how many persons have been killed while crossing streets against the red lights. That will give you the number of lives that might have been saved if those people had formed the habit of crossing only when the light was green. They walked to their death because they had never taken the trouble to form good habits. Records prove that it is four times as dangerous to cross against the lights as it is to cross with them.

Of course people are not going to form good habits unless they see the need. So one of our chief tasks in conserving human life is the education of everyone to know what the good habits are and to see the crying need for learning them. For there are three E's in this business of conserving human life—Engineering, Enforcement, and Education. We have already spoken of the important work of the safety engineer. And it is hardly necessary to say that unless the plans he works out for safe building and safe regulation are put into force, his work is wasted. But enforcement is really in the hands of the people. In a democracy like ours it is they who make the laws and they who decide whether those laws are to be obeyed. And the people will never see the importance of safety laws until they are educated to see the need of them.

How to Teach Safety to Babies

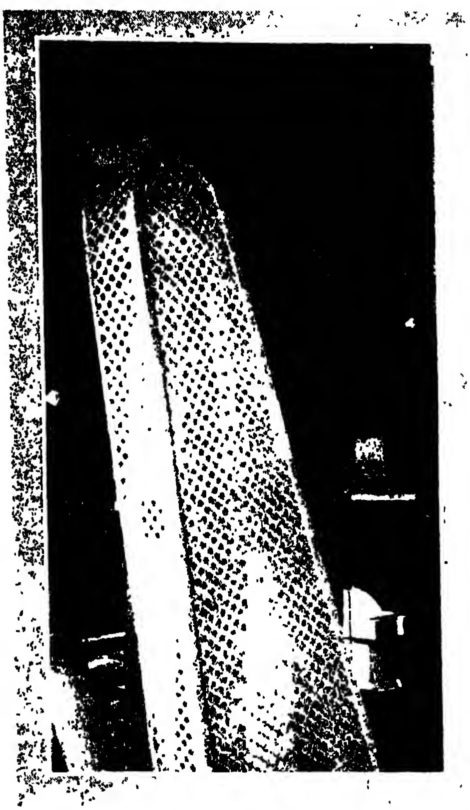
But more than that, education, and education alone, can teach people to form good habits, which are more important than anything else in conserving human life. This training can hardly begin too young. It must actually start with the babies. Of course the tiny tots will always be dependent on their elders for protection. Because they do not understand the world about them, and because they are active and curious, they must be watched all the time to keep them out of danger. Some of the saddest accidents of all are those that come to children through the fault of the grown people who are taking care of them and ten percent of all injuries to children come from this cause. We cannot be too careful of the little people in our own families and in the neighborhood.

When You See a Child in Danger

Whenever you see a youngster in any kind of danger make it your business to step in at once. Warn him when you see him playing a game of "King Arthur" with lances that have sharp points. Remind him that the traffic light has not yet turned green, when you see him about to start across a street against a red light. You may be saving him from being blinded or crippled—you may even save his life.

In the same way, warn him when you see him doing something foolhardy. He does it to attract attention, and will soon stop when he finds people think he is only silly. Do not laugh at his dangerous practical jokes. He does not intend to be cruel, but he should be made to see that paralysis, mutilation, or blindness may be the result of his horseplay. Let him know that he falls in your estimation by being so childish and stupid.

But keeping guard over the child is only half the battle. He must be taught that there are certain things he must never do, and in this way learn to take care of himself. Only then will he be relatively safe. Only then shall we save the lives of some of the fifteen thousand children who die of accidents every year.



Death lurks in whirring machinery. That is why factories take every precaution to protect the lives of their workers. The picture above shows how a dangerous spot may be guarded to protect people working around it.

This training must begin when the baby first learns to toddle. One of the first steps will be to teach him the meaning of the word NO. He must learn it beyond any shadow of doubt, and should respond to it quite automatically.

The Mighty Word "NO"

A good many authorities believe that, since he is too young to understand reason, this word can best be taught him by means of physical pain. It is something every parent must decide for himself, but certainly in this day when danger lurks everywhere, the word must be learned, even though it is taught by means of a sharp smack on the bare thighs. If the smack is used, it should be inflicted without any show of emotion, and at the instant when the word NO is pronounced. And the word should be spoken firmly—though not angrily—whenever the child begins to do something dangerous. Whether pain is used or not, he must be made to understand that NO is a mighty word which brings terrible results when it is disobeyed.

This is what is called "conditioning." It has nothing to do with punishment. If anything, it is a way to avoid punishment. It is a means of teaching the baby that there are certain things that must never be done. If every time he did something dangerous he immediately suffered painful, but not dangerous, consequences, the task of training him would be simple, for he would learn from experience. One slight burn would condition him forever against touching a hot stove. But one cannot wait till he is maimed or killed before teaching him never to step off the sidewalk alone. He must learn it while stepping off the sidewalk still looks very pleasant. In other words, he must learn that when he hears the word NO, something bad is going to happen to him unless he obeys it at once.

And the same thing is true of all the other dangerous things he will want to do. If you are firm he should soon learn never to do them. If you decide to teach him to respect the word NO by smacking him, a very few lessons will be enough. He should never have to be smacked after he is four or five years old. The word will then bring an automatic response. He will completely have forgotten when or how he learned it. And meanwhile

he will have learned to protect himself unconsciously in various ways. The formation of those good habits may well save his life.

About a third of the accidents to children take place at school, a fourth on the streets and public playgrounds, and still another third at home. At school children are most often hurt by falling from a tree or pole or fence—or by being struck by some object held or thrown by a playmate. Games are likely to be boisterous and the players excited. Here, as at home, good habits will often go a long way in saving ourselves and other people. We shall be careful how we throw things and how we fall over other people. We may as well learn at once that the conservation of human life means looking out for others as well as ourselves. It is only in that way that many accidents can be avoided.

The Right Thing at the Right Time

Now it must already have occurred to you that in the majority of cases the avoidance of accidents means recognizing the dangers and taking the proper means to avoid them. Since that is the case we shall think about the various situations in which we find ourselves and use self-control in always doing the right thing at the right time. No book can tell us all we need to know about the matter—our own intelligence will have to be relied on for that—but we can set down a few hints that will help in preventing accidents at home or at school. People who always keep these simple rules will have formed a number of good habits that will be more valuable to them than a large fortune would be.

Do not leave playthings or other objects lying on the floor or on the sidewalk. This is especially dangerous if there are elderly people in the family.

Always keep the halls and stairways clear.

Put sand or ashes or sawdust on icy steps and walks.

Keep away from bonfires and from fires in open grates.

Never put matches, medicines, poisons, and other harmful substances in places where little children can get at them.

Be careful when you are using or carrying a knife, a pair of scissors, or any other sharp or pointed instrument.

If you lose a needle while you are sewing never give up until you find it.

Do not hold or carry objects in your mouth.

Some Simple Safety Hints

Do not play carelessly with any kind of sharp or pointed object— an arrow or a spear.

Whenever you walk about the house in the dark hold your hands clasped and stretched out at arm's length in front of you.

Keep the sidewalk and the yard free from broken glass, fruit peelings, rusty nails, and tin cans.

Do not push or trip others.

Do not wrestle on hard pavements.

Do not throw stones or hard snowballs at people.

Our forefathers had to be on guard against accidents from burning lamps and candles. We do not need to worry a great deal about them to-day, but that mysterious force we call electricity can do a vast amount of damage unless it is properly handled. Because we do not see it we are likely to take silly chances with it, such as no scientist would ever take. Here are a few rules we should follow in dealing with electrical appliances:

Never touch a strange wire, whether it is hanging or lying on the ground.

Do not fly kites where the kite string may fall across a wire.

Never tamper with an electrical fixture.

Do not touch two electrical appliances at the same time.

Never hang anything on an electric cord.

Never touch an electrical appliance when your hands are wet.

Watch the insulation of appliance cords to see that it is not worn or broken.

How to Be Safe in an Elevator

One of the modern inventions that involves us in a certain amount of danger is the high-speed elevator. Though it is so well equipped with safety devices that it seems to be almost as intelligent as a human being, great care is necessary in getting on and off. One should step to the rear of the

Photo by Amos E. Neyhart

This is a high-school clinic for testing drivers. In it you can learn the length of your reaction time, the strength of your grip, and the extent of your ability to keep a steady hand when you are startled. Your hearing can be tested, and your eyes also, for it will be important to know if you are color-blind, near-sighted, lacking in depth perception, or a sufferer from barrel vision or blurred vision. Clinics like this one are growing more and more common in high schools over the country. It is a hopeful sign.

car and face the door. Never lean against the door. Of course no one should ever tamper with the elevator controls. But there are few people so stupid as to do that. Most elevator accidents happen to careless passengers who try to crowd on or off an elevator that is just starting. The three E's have done a great deal in reducing accidents of this kind. In 1936 elevators caused only 222 of the 110,000 fatal accidents in the United States.

How to Get on and off a Street Car

Like the elevator, the street car is most familiar to people living in the city. And just because they get so used to it people grow careless and meet with grave accidents in connection with it. First of all, one should be careful in crossing the street to reach the safety zone for boarding the car. While waiting one should not stand too near the track, especially if the car rounds a curve at that point; there is danger of being pushed either into the path of the oncoming car or of being struck by it as it swings around the curve. Of course it is dangerous to dash across the track just in front of a moving street car, or to hurry around behind it. And it is especially dangerous to leave the safety zone without first looking for oncoming traffic.

Making the Railway Safe

Far more hazardous than the street car is the railway. For almost a century after it came into use in America it claimed its victims by the thousands every year. In spite of the many improvements and the widespread effort to educate the public, the number of persons injured and killed by railway trains every year is still unbelievably great. Such inventions as the block system of signaling have almost done away with wrecks, and improved switches and automatic couplers for cars have greatly reduced the number of accidents among trainmen. Yet hundreds of people meet death every year when walking on forbidden railroad tracks or carelessly driving across grade crossings. Even safety gates at crossings, now required by law in nearly every state, fail to halt the heedless motorist, for hundreds of drivers crash right through the bars in a foolish effort to beat the oncoming train. It takes more than watchmen or gates or signs at crossings to put an end to such disasters. That can only be done by teaching people never to take a chance.

No one should ever cross a railroad track without first stopping, and listening, and looking both ways. Railway tracks, bridges, and embankments should be held as dangerous as a field of battle. Boys and girls should never play in railway yards, crawl under or over cars, or try the perilous feat of stealing a ride. Even passengers aboard trains should use precaution. To leave or board a moving train, to ride on the platform, or to put head or arms out of the coach window is an invitation to accident and often to death. The railway companies have for years done all they could do to make their trains safe for the public and to save people from accident on the tracks. They have accomplished wonders in making their trains safe, but the public will have to do its share!

The Greatest Cause of Accident

As a matter of fact the public is hard to save, as the countless thousands of accidents caused by the automobile prove only too plainly. This magnificent invention, which is of such enormous value in modern life, is at the same time the greatest cause of accident with which we have to contend. The millions of automobiles now in use have complicated living in a way we should never have dreamed of only a few years ago. In spite of instruction given in schools, in spite of police regulation of drivers, in spite of traffic rules, the number of automobile accidents mounts steadily.

Traffic Accidents Must be Stopped

It is here that education has the most to do. In the first place, people must be aroused to the fact that traffic accidents are not necessary. Once travel by water was very dangerous. To-day it has been made one of the safest forms of transportation in the world. Once train wrecks filled the newspapers with horrors. To-day we rarely read of one. There is no reason why the automobile should yearly wipe out enough people to fill a city. To allow it to go on is criminal and stupid.

But if it is to be stopped, everyone—and that means you and me—must awake to the fact that he has a personal responsibility in the matter. The saving of human lives lies with *us*. If we do not help by lending our influence and coöperation we shall certainly be sharing the responsibility for killing and maiming thousands of people every year. There is no way of shrugging our shoulders and shifting the responsibility to someone else. We all use the streets and highways. We all must help or hinder in this, one of the greatest coöperative enterprises of the civilized world.

How a Safe Highway Is Built

To begin with, we all must help to arouse people to the need of conserving human life on the roads. Engineers have made great progress in designing safer highways, but if people are going to go right on building the same old-fashioned roads, the work of the engineers will be wasted. When you learn that a new highway for fast traffic is to be built in your neighborhood, ask if sharp curves will be straightened, if there will be "roundabouts" and "cloverleafs" at dangerous intersections, if the surface is to be smooth and firm and made of a material which will not be slippery in wet weather, if the "lanes" are to be at least eleven feet wide and the road to be divided down the center, so that it will in reality consist of two one-way drives. Ask if blind "dips" and steep grades have been leveled out and blind curves done away with, if the shoulders are to be wide and firm, if the roadbed is to be flat instead of "crowned" - that is, higher in the center—and if it is to be banked on the curves.

It is not necessary for every road to be built so carefully, but crowded highways are much safer if they follow these specifications. It is especially important that bridges or underpasses should replace grade crossings at railroad tracks on busy highways, and that gates or bells should be installed at less crowded intersections. Yet even these very necessary safeguards are lacking in many places. Only an insistent demand on the part of the people can give our country safe roads.

Engineers have developed the automobile until it is a mechanical marvel, but the owners must do their share to keep their cars in safe condition. Talk about the fact that

Photo by Amos F. Nevhart

These high school students are not going to be "just fair' drivers. They will be expert, and probably will never be the cause of an accident. Their teacher is trained to his task, and their school is doing everything in its power to help him. At the moment he is giving a lesson in lubrication.

tires worn smooth or otherwise injured are very dangerous and cause a large number of accidents. Spread the news that some states require that brakes be tested periodically—does yours?—and that some states require steering gears to be tested—does yours? Notice how many drivers dash over the roads with dirty windshields—a grave handicap, especially when the driver is facing into the sun. In discussing a night accident, ask whether both drivers had good headlights, or whether dirty or scratched reflectors and lenses, and old bulbs out of focus, had reduced the power of the lights, perhaps by more than fifty percent.

The Deadly Carbon Monoxide

And remind your careless friends that tests have shown that one car in twenty on the road contains enough carbon monoxide (mō-nŏk'sīd) to impair the driver's judgment so badly as to cause an accident. This deadly gas seeps into the car through loose floor boards and at other such points, and comes from a defective exhaust system. It can bring quick death if you leave all the windows of a car closed while the motor is running, or if you let the motor run even a few minutes in a closed garage.

Courtesy Saves Lives

Engineers and public officials have worked out various regulations for handling traffic. Discuss these with other people. When they are violated, ask what the penalty is. If the penalty is not applied, inquire why the law is not enforced. Is it impossible of enforcement? Is it perhaps an unwise law? Is enforcement lax? If so, why? Work also for uniform traffic regulations throughout the United States. People have been killed in one state for doing what was legal in another state. Many states have schools for traffic officers, and the "cop" is a traffic expert. He has come to be the driver's friend.

By constantly talking about all these matters people will educate one another to the need of safety. Do not conceal your fear when you ride with a driver who does dangerous things. The pressure of opinion

will do him more good than any amount of preaching. And commend sound, skillful drivers. That too will bear weight with your careless friends. If you, as a driver, receive consideration from another driver, thank him, if only by the wave of a hand. He will appreciate it, and will be all the more likely to show courtesy another time. And courtesy saves lives.

Most important of all is the need of educating the individual driver. We are very careful to train our aviators, but some states do not even require a test before letting a driver go out on the road with a car. A third of the population of our country knows how to drive—that is, 40,000,000 persons—but the percentage who are really expert is very small. A large number are actually incompetent. Until they are eliminated in one way or another, Death will continue to sweep along our highways with terrible results.

Why Do People Drive Badly?

Now there are various reasons why people drive badly. Many have never really learned to handle a car. Others are expert enough in the actual manipulation of the machine, but have no clear understanding of what is safe and unsafe on the road. Still others are childish in their attitude toward danger—they are either too timid to drive well or are reckless or discourteous or unsportsmanlike, and so bring themselves and others to grief. To drive expertly is a sure sign of maturity, even though the person who does so is still in his teens. To drive recklessly is a sure sign of childishness, even though the driver who does so is graying at the temples. Of course there are a certain number of persons who are physically or mentally unsound and for that reason should not handle so dangerous a thing as an automobile.

So if you are going to direct the harnessed power of forty or sixty or eighty horses in crowded traffic or at high speed through the open country, find out first of all whether Nature has made you equal to the task. Can you tell red from green traffic signals, or are you color-blind? Is your sight weak or blurred? Do you suffer from "barrel vision" —which means that you do not see out of the tail of your eye but must turn your head in order to glimpse objects at the side? Are you weak in "depth vision"—which means that you find it hard to tell just how far away from you an object may be? Are your eyes sensitive to light, so that oncoming headlights will blind you if you undertake to drive at night? You can be tested for all these defects, and so learn just how well your eyes fit you to be a driver.

Are You Strong Enough to Drive?

Of course certain diseases will make you unsafe at the wheel of a car. Epilepsy, paralysis, insanity, various kinds of heart trouble, and locomotor ataxia all incapacitate a person for driving. Deafness is a serious handicap, and so is muscular inability to grip the wheel. Anyone who has a grip of less than sixty pounds in the stronger hand and fifty in the weaker will be unable to control a car in certain emergencies.

Then there are various mental and emotional traits that will make you unsafe at the wheel. If you have bad habits of attention you had better let someone else do the driving, for in these days of speed even a slow driver must always be alert. If you are excitable and tend to lose control of your wits in an emergency, never take a car out on the road. And it will be better for you to let someone else drive if you are timid. If you are likely to lose your temper, do not try to handle a car. Your judgment will almost certainly be impaired at the instant when it should be soundest. If you are egotistical, fond of bragging and showing off, discourteous, a "poor sport," a "chiseler," or a bit of a cheat, you are the kind of person who is likely to have an accident.

Be Careful When You Are Tired

Of course there are temporary states that make you unfit to drive. If you are ill, worried, over-tired, sleepy, or in any other way under par, your attention and judgment will flag and you will react more slowly. A powerful sedative will produce the same effect. If you feel tired while you are at the wheel of an automobile, rest and walk about a few moments or turn over the wheel to someone else. Drowsiness is especially dangerous. Always stop and stretch or, if

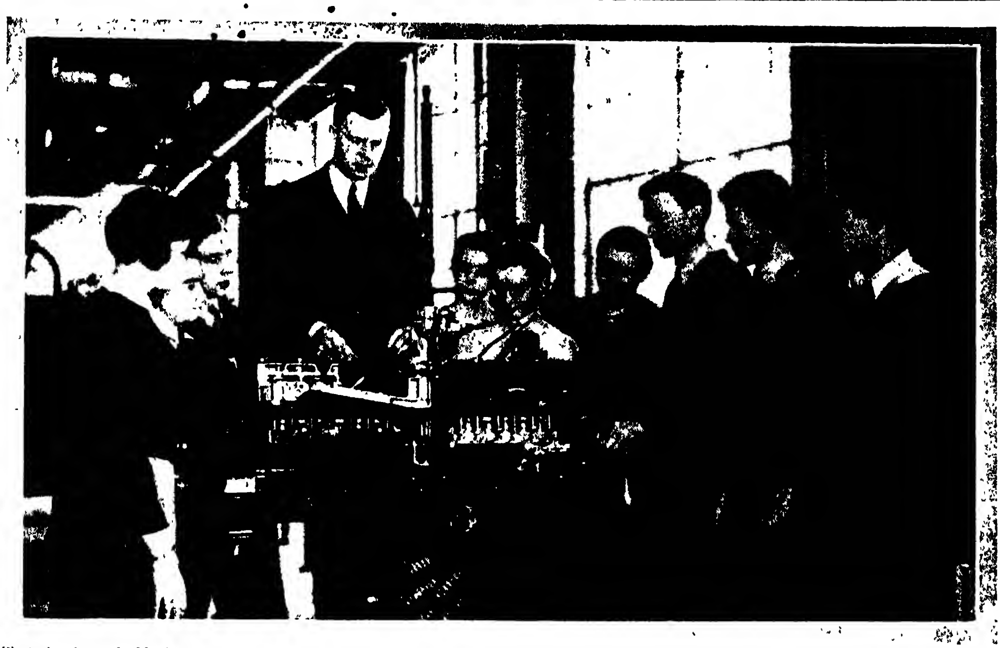


Photo by A. E. Neyhart

Four girls and five boys! For in this high-school class in driving the girls get the same instruction as their brothers. And Professor Amos E. Neyhart who originated the training of teachers for high-school courses in driving—says that the girls are just as interested as the boys in seeing how an automobile works—and just as quick to understand it. All they need is the chance. Here the class is inspecting a motor from which part has been cut away in order to show how other parts work.

possible, take a nap when you feel it coming on. Strong tea is perhaps the best thing to counteract it. Records show that accidents are much commoner late in the day, as people grow tired and night comes on. Yet that is usually the time when traffic is heaviest. The only way to guard against accidents in the late hours of afternoon and after dark is to reduce your speed greatly. In cold weather it will be dangerous for you to drive if you are chilled. Many airplanes crash because the pilot was numbed with the cold.

How Long Is Your Reaction Time?

There is one mental qualification for driving which is very important. You must have a normal "reaction time." This means that under ordinary driving conditions it should not take you more than three-fourths of a second to get your foot off the accelerator and on the brake, measuring from the instant when you see a given signal. People vary greatly in this matter. Some give a muscular response in a third of a second. Others take more than a second.

When you realize that a car going sixty miles an hour will travel eighty-eight feet in a second, you will see why a man who is slow to react is a menace to himself and others when he takes the wheel. This is especially true if he is obsessed with the speed mania—for the faster a car is going, the longer it takes to stop it after your foot touches the brake. The "reaction time" measures only the length of time your foot takes to reach the brake. The "braking time" is much longer, and varies with differing conditions. As people get older their reaction time lengthens—but many young people have reactions that are naturally slow. There are instruments for measuring this. If you know or suspect that your reaction time is longer than normal, never drive fast. If it is very slow, never drive at all.

Alcohol and the Reaction Time

In this connection it is well to add that even a small amount of alcohol can double a person's normal reaction time—and it can do so without a man's suspecting that he is

feeling the effects of it in any way. Never, under any circumstances, drive when you have had a drink. Your habits will be disarranged, your reaction time slowed down, and your judgment impaired. *No one with alcohol in his body is fit to hold the lives of human beings in his control.* Yet day and night, on all our highways, people who have been drinking dash along at speeds which would be dangerous even if the driver were sober. Death no longer rides the midnight express—he sits behind the steering wheel, with Drink for a traveling companion.

Are You Going to Be a Good Driver?

Now let us suppose that you are a normal person, without physical, mental, or emotional handicap. And let us suppose that you want to be a good driver—the kind who never has an accident and never causes anyone else to have an accident. It may be that you do not drive at all, it may be that you drive moderately well and would like to improve—or it may be that you drive very badly and think you are an expert. In any of these cases, how are you going to become a skillful, responsible driver?

First of all, you will put yourself in the hands of a master of the art. It may be that you will do this by hiring a professional teacher; it may be that among your friends there is a skilled driver who will be amiable enough to teach you. Or it may be that you are fortunate enough to be enrolled in a high school where driving is taught. In any event, do not imagine that you can "just pick it up"! If you have a teacher who is less than competent, you will probably reproduce all his weaknesses—and then go through life thinking that no one has anything to tell you about the matter!

A "Poor Sport" Is a Poor Driver

Your whole learning process will consist of the formation of good habits—habits of skilled muscular control, habits of sound judgment, and habits of courtesy and sportsmanship. And strange as it may seem, the last are the most important of all in preventing accidents. A moment's thought will show the reason for this. A courteous, sportsmanlike driver never tries to "beat the other fellow" to the intersection. He never refuses to let another driver pass. He never is a "roadhog." He never terrifies and confuses pedestrians by blasting a way for himself with his horn. He recognizes that others have the very same rights that he has, and is willing to yield a point if need be, for he realizes that another driver may be aged, a learner, naturally handicapped, timid, incompetent, or confused. He knows that when he takes the wheel in his hands he becomes responsible for the safety of every one who may come in his way.

Now we cannot go into details here as to how a driver must handle the wheel and brakes. To drive your beautiful piece of machinery in the way it deserves takes a thorough understanding of its behavior and a vast amount of practice. It should be second nature to you to do all the right things—as natural as walking. Until the wheel and pedals are like extensions of your own arms and legs, to be handled as easily and with as little thought as you give to the management of your hands and feet, you are not ready to meet an emergency on the road. Never go into traffic until you know your car well and have learned to control it.

What Are the Expert's Driving Habits?

And when you have learned, then what? Then you will begin to form those habits of sound practice and good sportsmanship which are the real mark of the expert. There can be no set of rules to cover every emergency, but good habits will go a long way toward guiding you aright when the crisis comes. Let us see what some of them are.

To begin with, you will always adapt your speed to conditions. It is silly to say that a given speed is "safe." It all depends upon you, your car, the road, and a number of other circumstances. There are plenty of times when a speed of ten miles an hour is extremely dangerous. The good driver knows from experience that safety depends upon conditions, and that there are many occasions when he must slow down to a walking pace to be sure of avoiding an accident. Unfortunately many people who are otherwise very skillful in handling a car seem to be completely ignorant of various laws of physics

that are as certain to act as water is certain to flow downhill.

The main reason why fast driving is dangerous is that at high speeds it takes proportionately very much longer to stop your car. Or, to put it in another way, the "braking distance" increases, roughly, as the square of the speed. If you are going at 15 miles an hour on a good road you can bring your car to a standstill 15 feet from the spot where you put your foot on the brake—that is to say, you can do this if your brakes are working perfectly! Often they are not. But suppose you are going 30 miles an hour. Then you will have to travel 62 feet before you can stop your car. And if your speed is 60 miles an hour, your braking distance will be 248 feet. In other words, to slow a car down from 50 to 40 miles an hour takes nine times as long as slowing down from 10 to 0 miles an hour—a fact few people know.

STOPPING DISTANCES

Under most favorable road conditions

(Based on effective four-wheel brakes and driving on a straight, level, smooth, hard-surface, dry highway)

IF YOU GO THIS FAST:		Before your mind and body react* to a warning of danger, you will go this distance	You will go this much farther from the time your brakes first begin to take effect until you come to a full stop	In other words, you will travel this distance from the time you are first aware of danger until your car comes to a full stop
(Miles Per Hour)	(Equivalent Feet Per Second)	THIS IS "REACTION-TIME DISTANCE" (Feet)	THIS IS "BRAKING DISTANCE" (Feet)	(THIS IS "TOTAL STOPPING DISTANCE")** (Feet)
10	15	11	7	18
15	22	16	15	31
20	30	22	28	50
25	37	27	43	70
30	44	33	62	95
35	51	38	84	122
40	59	44	109	153
45	66	49	135	184
50	73	55	172	227
55	81	60	216	270
60	88	66	248	314

* Average reaction time of 0.75 second.

** The figures in this column are for average reaction time and good brakes. The total stopping distance from 30 m.p.h. for a person with 2-second reaction time driving a car with poor brakes would be 88 plus 100, or 188 feet (or nearly twice the distance given above).

The remainder of the illustration and charts in this article are reproduced by courtesy of American Automobile Association from Sportsmanlike Driving Series.

Study this chart carefully. It will tell you a number of things that will amaze you. Even if you do not drive and perhaps never intend to—these facts are important to know. The pedestrian, as well as the driver, should bear them in mind.

What Is the "Stopping Distance"?

Of course we have not given you the "stopping distance." To get that you must add the "reaction time distance" to the braking distance, for of course your car is traveling all the time that your foot is moving from the accelerator to the brake. So if you have a reaction time of three-fourths of a second, the total stopping distance for a speed of 15 miles an hour is 31 feet. For 30 miles an hour it is 95 feet. And for 60 miles an hour it is 314 feet.

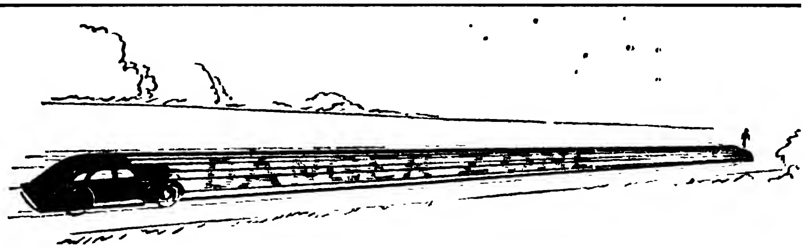
Now 314 feet is a long way! Measure it off and you will begin to see the danger of fast driving. Then add to all this the fact that our figures apply only to ideal conditions—for driver, road, and car! It at once becomes clear why high speed is one of the chief causes of highway accidents.

"But how am I to know what is a 'safe' speed?" you will ask. "Surely you would not have me travel always at fifteen miles an hour!" By no means. For that too would be dangerous. Experience will have to guide you, but knowledge will be a help. So let us see what are some of the facts about speed under varying conditions.

In front of every car that is in motion there stretches a "danger zone." It takes in all the distance that your car will have to travel before you can bring it to a standstill. If you are tired, cold, ill, worried, excited, inattentive, or under the influence of alcohol, your danger zone will be lengthened, for anything that increases the reaction time lengthens the danger zone.

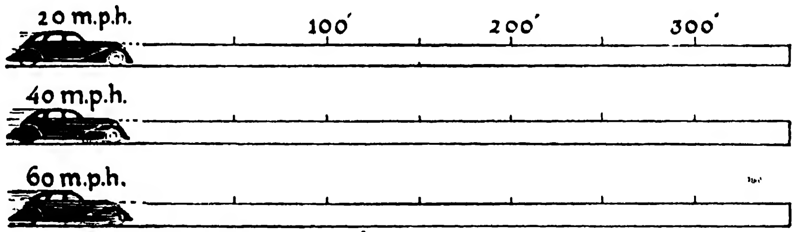
If the road is wet, oily, icy, or slippery from any other reason, the danger zone is very much lengthened, for then the brakes cannot "take hold" so effectively. The wheels, if they cease to turn, just slide over the ground. The same is true if the surface of the road is uneven. The danger zone is lengthened greatly when the tires are worn, for smooth tires will slide along the road instead of gripping its surface. Bad brakes also lengthen the danger zone enormously.

It is at night that the length of your



You should learn to think of your "danger zone" as if it were part of your car—in almost the way that the hood is! The instant your car starts to move, your danger zone stretches out in front of you. It is the distance you will have to travel before you can bring your car to a stop. Of course it is an elastic thing, for it varies with your speed and with certain other factors. But it should always be clear of obstructions, for within its length you will be completely unable to stop your car.

danger zone is especially important. If you stretch it beyond the distance lighted by your headlights, you become, to all intents and purposes, nothing more than a blind man at the wheel. Even a small child can understand the reason for this. In the daytime, if the road is good, a driver can usually see at least an eighth of a mile ahead—660 feet. Often he can see much farther. At night his headlights reach at most a very short distance—probably no more than 250 or 300 feet if they are very strong, and usually not much more than 150 feet. As a rule a driver can see clearly only about 100 feet ahead.



Speed is only one of the factors that affect the length of your danger zone. Others are the condition of your tires, of your brakes, of the road's surface, of the light and the atmosphere, and of your own mind and body. In the diagram above you will see three cars, presumably traveling at three different rates of speed. Can you figure out what would be the length of the danger zone of each car, if all the other conditions were perfect? On another page you will find a chart to help you—but it is well to memorize these facts.

Now suppose that, seeing only 100 feet ahead, he nevertheless drives at forty-five miles an hour. His danger zone will then stretch 184 feet ahead of him, though he can see clearly for only 100 feet. In other words, if there should be an unexpected obstruction in the road, if a child should start to cross it, if suddenly a sharp curve should loom up, there will be no hope of slowing down in time. Disaster will be practically certain.

This is why an investigation in one of our states showed that two-thirds of the deaths from automobile accidents in the state came from disasters that happened between six at night and six in the morning. Yet during that interval there were only half as many cars on the road as there were in the daytime, and in proportion there were still fewer pedestrians. In other words, drivers did not slow down enough to bring their danger zone within the distance that they were able to see ahead.

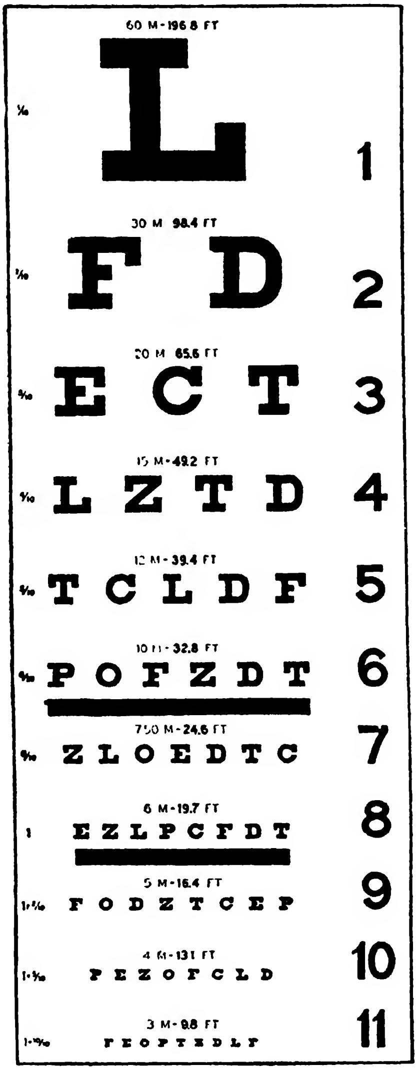
Authorities on the subject say that hardly one driver in a hundred realizes how much more dangerous it is to drive fast at night. Yet, as we have said, the arithmetic of it is so simple that even a small child can understand it. If drivers would always drive slowly enough to keep their danger zones as short as the distance that they can see clearly, our appalling number of night tragedies would cease. With lights that show the road clearly for only a hundred feet, thirty-five miles an hour should be the maximum speed. Driving in rain or snow is like driving after dark. You cannot see ahead. In a heavy storm pull well off the road and wait for the air to clear. For the same reason never drive into smoke—and go very slowly in a fog.

An added danger after dark lies in the fact

that oncoming headlights dazzle a driver who must meet them, and leave him partly blinded for at least seven seconds after they have passed—for that is the length of time needed for the pupils of his eyes to open again. If a pedestrian, especially one in dark clothes, steps into the danger zone of a car during those seven seconds, he must reckon that the driver who is bearing down upon him is partially blind. A great many accidents happen in this way.

The expert driver will always reduce his speed before he meets a car at night, and will keep it down until his eyes have had plenty of time to readjust themselves again. He will avoid looking into the headlights of a car, but will keep his eyes to the right of it. He will show his sportsmanship by "depressing" his own lights when he meets another car—that is, by throwing them down toward the road—or by dimming them. If every night driver would do this, a great many accidents would be avoided. Do not wait till it is dark to turn on your lights. Turn them on soon after sunset.

There are other conditions under which a car should go slowly. A speed that is safe enough on a straight road will bring disaster on a curve. It is not only that the curve may hide some obstruction within the danger zone—for instance, a car coming on the wrong side of the road, a scattering group of children, or a bad automobile accident. The worst danger lies in the fact that if you are going too fast your car cannot be held to the curve, but will go off the road. For it is the tendency of moving objects to travel in a straight line. The action of what we call centrifugal (sĕn-trĭf'ū-găl) force pulls a large number of cars off the road on curves. So always slow down *before* you get to the curve. Then you can pick up speed as you go around it, for you will have your car "under control," as we say, and will know what lies ahead. Never under any circumstances take a curve so fast that you cannot keep to your own side of the road. To do so will be certain to bring disaster some time or other.



This is a Snellen chart, for testing the clearness of your vision. Place it in a good light 51 inches from your eyes, and on a level with them. Then test each eye separately. Do not close the eye you are not testing; hold a piece of cardboard in front of it. After you have tested each eye separately, test both eyes together, this time reading the letters backward. If your vision is normal you should be able to read line 8 with each eye.

In fact, you must keep to your own side of the road at all times, even when traffic is light. Do not be a "roadhog." Courtesy in driving pays high dividends—just as it does in so many other phases of life. Do not be unsportsmanlike when you meet another car on a narrow way. Give it half the road. If you think you may get into trouble by doing so, do not solve the problem by keeping the center of the road yourself. Stop and get out and see how matters stand. Then both drivers can decide what is best to be done.

Never pass pedestrians on your side of the road when you are about to meet another car. If you suspect that you have injured another car or a person, *always* drive up to the side of the road and stop.

Give your name and address if harm has been done. Never try to get away. It will only make matters worse for you in the long run if you do.

A great many fatal accidents come from traveling too fast over roads that are wet or covered with snow, ice, oil, or wet leaves. Under such circumstances a car will skid, for the wheels cannot "grip the road." Then if the brakes are put on to reduce the speed, things are likely to go very badly, for to jam on the brakes when a car is skidding is the worst thing one can do. It greatly increases the force of the skid and is likely to overturn the car.

If you find your car beginning to skid, first of all make up your mind that no matter what comes you will keep your head. It will be very necessary for you to do so, for you will be in real danger and the experience will be exceedingly terrifying. Turn your front wheel in the direction in which your rear wheels are skidding—not too sharply, but enough to carry the car ahead along the road and so overcome the sideward movement. As the car straightens out, you will straighten the front wheels. Keep the clutch in, and whatever you do, *keep your foot off the brake!* Do not take your foot off the accelerator with a jerk; and as you get under way again, feed the gas very, very slowly. One experience of this kind will cure any driver of a desire to go too fast over slippery roads.

Look Out for a Skid!

Of course worn tires greatly increase the danger of skidding, and so do certain kinds of surface. It is hard, for instance, for the tires to grip an uneven surface firmly. Taking a curve too fast is very likely to start a car skidding, especially if you are driving on a crowned road—that is, one which is higher in the center than at the sides—for then a car is likely to slide down toward the side of the road.

DRIVING SPEED ON A CURVE

Speeds at which a car can be safely driven on a curve of 600 ft. radius under various conditions

Condition of Road Surface	KIND OF CURVE		
	Banked*	Flat	Crowned**
DRY	48	42	38
WET	38	30	21
ICY	32	21	1

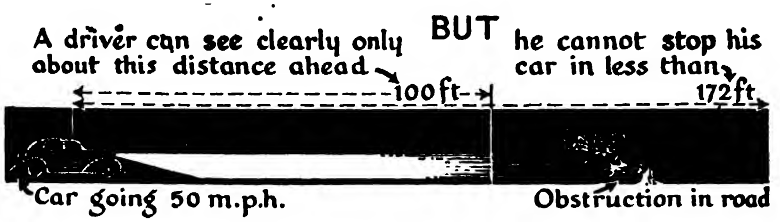
* Slope of banking=0.06
** "Outside" of crowned curve to the left, slope of crown—0 05

Most drivers have very little real knowledge as to the speed that is safe in rounding a curve. This little chart will tell you a number of interesting things about it.

A combination of certain of these conditions can be extremely perilous. For instance, experts warn us that in rounding the outside of a curve with a 600-foot radius on an ordinary crowned road that is covered with ice, we should reduce our speed to a mile an hour. Now no one would ever think of eight or ten miles an hour as an excessive speed, yet under these circumstances it would be almost certain to bring disaster. That is what we mean when we say that speed must be controlled by conditions. An expert knows how to do this and uses his knowledge.

In general, curves must always be taken more slowly on a crowned road than on a flat road, and more slowly on a flat road than on a "banked" road—that is, on one which slopes toward the inside of the curve. The banking tips the car away from the outside of the curve and so throws the weight on the side away from the one where centrifugal force is at work to pull the car off the road. We have explained centrifugal force more fully on other pages of these books—but whether a good driver understands the theory of it or not, he never takes a chance with it.

Besides having all this knowledge at his fingers' ends, your expert knows that speed is a hard thing to judge. He realizes that when he has been driving at sixty miles an hour, forty miles an hour will seem slow—yet under the best of conditions his danger zone at that speed will stretch ahead of him 153 feet. In other words, he will be going much too fast to cross an intersection safely or to avoid running down a pedestrian who steps out suddenly from between cars parked in a city street. So a good driver watches his speedometer. When he crosses an intersection he *drives slowly*. When he enters a



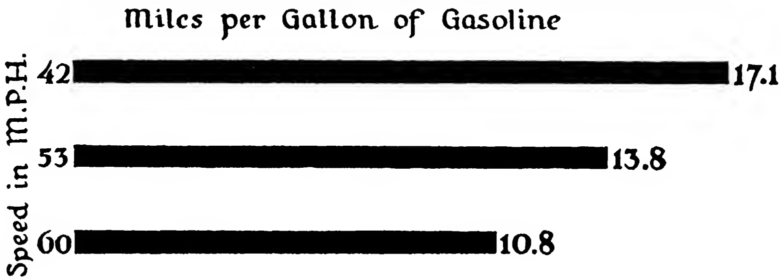
If you will study this diagram you will understand why our roads are full of tragedies by night. Our driver who is dashing along so recklessly at fifty miles an hour has no premonition that a fallen tree stretches across his path so near at hand that he will be unable to stop before he crashes into it.

town he brings his speed down to the official speed limit, no matter what his rate has been in the open country. Under all conditions he keeps his eye on the dial.

Of course it is important to reduce your speed going down a hill, for then your danger zone is lengthened and your car can easily get out of control. Never coast down a hill by disengaging the clutch, for in coasting the car will have nothing but the brakes to check its speed. As long as the engine is in gear, it operates as a brake and prevents the car from slipping ahead too fast. In fact the engine should always be put in second gear for steep grades, for then the wheels will turn only as fast as the engine turns them. On unusually steep grades a good driver will go into low gear.

All this is a great saving of brakes, which wear out fast under rough usage. No good driver ever depends on brakes alone to get him safely down a bad hill, and when he does find it necessary to use them, he applies them for a moment and then releases them. We call it "snubbing." The short moments when the brakes are not applied keep them from getting too hot. Brakes are handled in the same way if the driver has to reduce speed on a road that he fears may be slippery. By barely touching the brakes for an instant at points in the road that seem dry or free from ice, he reduces his speed without throwing the car into a skid.

There are many ways in which moderate driving is more economical than speeding. Few drivers seem to realize that a great deal more gas is needed to carry a car a given distance at high speed than is needed for moderate speed. Driving at sixty miles an hour takes at least half again as much gas for the same distance as driving at forty miles. It also takes a great deal more oil, it is two or three times as hard on the tires, and a good deal harder on the brakes.



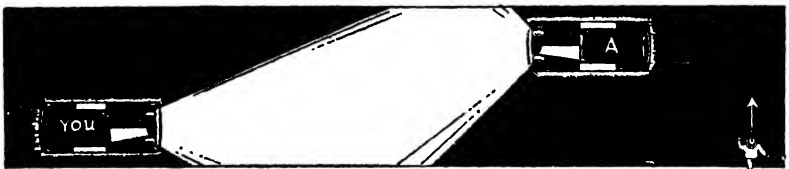
High speeds are expensive in money as well as in human life. The faster you go, the more gasoline it takes to drive your car a given distance. This chart will give you an idea of what the proportions are.

In fact skillful driving can reduce the consumption of gasoline amazingly. The best drivers never dash up to an intersection and then jam on the brakes. To do so is a waste of power—and consequently of gasoline. Instead, your good driver takes his foot off the accelerator some little time before he is going to stop, depresses the clutch, and lets his car coast up to the intersection.

And even if he is not trying to save gaso-

line, an expert will always slow down a considerable time before he comes to a stop at an intersection. Only then will he be sure of shortening his danger zone enough to be able to avoid killing people who step hastily in front of his car, or to keep him from colliding with a car coming from the side at top speed. Especial care must be taken at "blind" intersections, where walls or shrubbery reach almost to the highway and make it impossible to see what is coming on the intersecting road. Sometimes a bus or truck parked at the corner of an intersection will cut off a driver's view, and so will a trolley car.

turn, and all of them are likely to cause trouble. The best way to turn to the left is to proceed into the intersection, keeping to the lane you were in and turning in such a way that your right hind wheel would pass just to the left of the intersection of two imaginary lines, one drawn down the center of each of the intersecting highways. As you turn, keep to the left-hand lane of the highway you are turning into. In a city, of course, there often is an officer or a sign to direct you. When you make a right turn, keep well inside the right-hand lane in both highways. But if you are turning into a city street where cars are likely to be parked, be



A great many pedestrians are killed in this way after dark. A driver's eyes are partially blinded by the glare of an oncoming car, and remain so for a few seconds after the car has been passed. During those few seconds he does not have a clear view of the road ahead of him. A pedestrian may easily be run down during that short interval of time—especially if he happens to be wearing dark clothes.

The rule here, as in so many other places, is "never take a chance." At least three hundred feet before you reach the intersection, signal your intention if you intend to make a turn. You will do this by extending your left arm according to the signals in use in the state in which you are driving—and never drive in a state or city without finding out what its regulations are. You will also signal if you find that you are going to stop.

What to Do at an Intersection

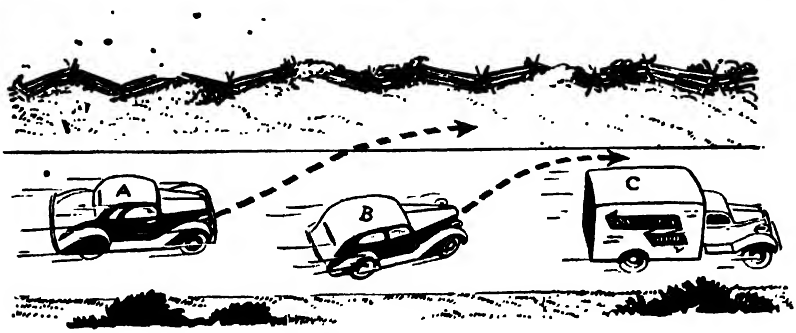
When you stop, draw up close to the intersection, so that you may see as far as possible in both directions; but if you are in a city leave room for pedestrians to cross in front of your car without having to go out into the stream of cross traffic. If you are on a four-lane highway and intend to make a left turn, you must work your way into the left-hand lane before you reach the intersection, and if you are going to make a right turn, you must work your way into the right-hand lane.

There are a great many wrong ways to

sure to leave the width of a car between your car and the curb.

If you are obliged to make a U-turn in the city—that is, to reverse your course—you had better make it in the center of a block rather than at an intersection—and never attempt it if you are likely to hold up traffic. Never turn in front of a fire station. On the open road, never make a U-turn if another car is coming, or if a hill or a bend in the road shuts off a clear view of the highway in either direction.

Never run through a red light at an intersection unless it comes on after you have started across or when you are so near the intersection that to stop short would give the passengers in your car a perilous jolt and endanger the car behind you. Do not proceed through an intersection if the green light has given place to a warning light of white or yellow. Stop as if the light had already turned red. Whenever you stop—but especially at an intersection—put your car into neutral at once. Then there will be no



It is in situations like this one that accidents are likely to occur. If the driver of car B had signaled his intention of passing the truck, car A would not now be in danger of colliding with him.

danger of your starting unintentionally. And do not start until the green light has come on. Feed the gas with great care in starting, for to bump the car in front of you may send it into a pedestrian who is late in reaching the curb. If you are preparing to stop for a light that has just turned red, signal your intention to the driver behind you. He may not have seen the light change.

Keep Your Eye on the Mirror

And never slow down or stop on the open road without first looking in the mirror and giving the signal. It is only courteous to do so, and may save a number of lives. Never stop suddenly if you can avoid it. Be as conscious of the car behind you as you are of the one ahead. Keep to an even speed and do not straddle two lanes. Often the road-hog is so poor a driver that he does not know where his four hoofs are, but that does not excuse him. He should learn to handle his car!

If you are going to shift from one lane to another, always look first in the rear-view mirror. If you are turning into the lane at the left, look behind you through the windows at the left and signal your intention clearly. Drive straight. If you wobble about, even though you stay in your own lane, the driver behind you will think you are about to change lanes and will act accordingly. Leave some sixty or seventy feet between you and the car in front of you except when the highway is very crowded and traffic is moving slowly. Then you may safely move up near enough to prevent a car from slipping in ahead of you. You will be going so slowly that your stopping distance will be short in any event.

Watch the whole highway carefully. Never fail to observe "STOP" and "SLOW" signs, for they are put up for excellent reasons. Enter a highway with the greatest care, whether it be from a side road, an alley, or a garage. As you drive, keep your eye on the surface of the road, to make sure that it is unbroken. An unexpected hole taken at high speed can ditch your car, and so can a sudden change in the nature of the surface—for instance, from concrete to macadam. Sometimes ice will form very quickly on a winter afternoon. Be careful never to drive out on the shoulder of a road except when your car is going *very* slowly, and then make sure that the shoulder is firm. Of course this rule must sometimes be broken in a dire emergency. Be careful on trolley tracks, for your car is likely to skid on them, and often it is very hard to get off them if you have been driving along the rails. In crossing a trolley track, be sure not to cross at too sharp an angle.

Watch for Blind Entrances

Look out for "blind" entrances to your road, and for highways joining yours. Remember the rule which gives the right of way to a car entering the highway from the right. If it is your custom to drive up and down a mountain, learn whether it is the practice to give ascending or descending cars the right of way.

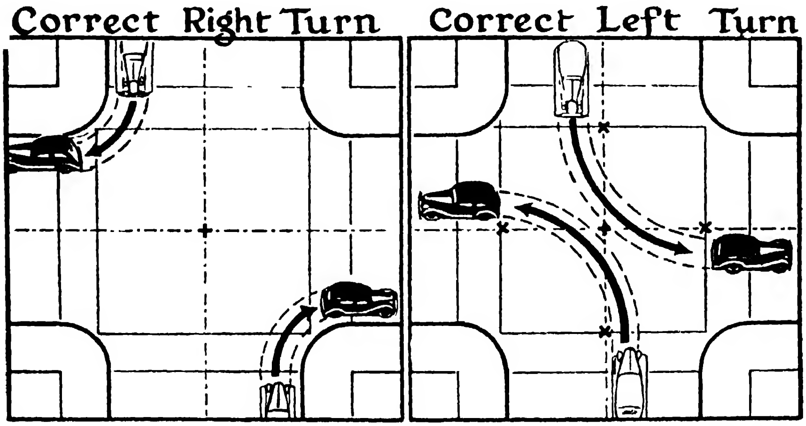
When you find yourself in a line of cars, keep your eye not only on the first car ahead but also on the second and third in front of you. Be on the alert for accidents threaten-

ing to develop within the next hundred yards. Is the driver who is passing the third car ahead about to cut in too quickly? Shorten your own danger zone at once—that is, *slow down*! If he collides with the car he is passing, the cars coming behind will pile up on the two that have collided, and there will be a terrible disaster. See to it that your car is not in the heap.

Is the second car ahead of you threatening to pass on a curve or near the crest of a hill? Slow down at once. The driver of that car is doing one of the most dangerous things that can be done on the road. If he should collide with an oncoming car that suddenly bears down upon him, see that your own stopping distance is short enough for you to be able to keep clear of the débris. Notice situations that are likely to result in an accident, and try to figure out what you would do in this, that, or the other emergency. To have a wise course of action worked out ahead of time may help you to act promptly and wisely if the emergency should ever arise.

How to Pass a Car on the Road

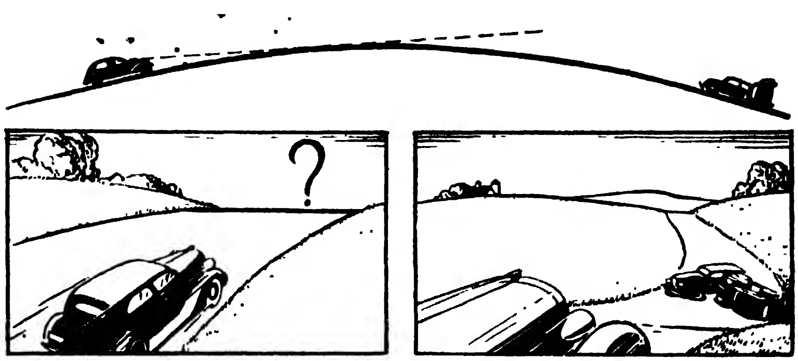
A great many accidents occur in overtaking and passing other cars on crowded highways. Never pass on the right unless you are moving in a lane of cars that happens at the moment to be going faster than the cars in the lane to the left. Drive in the right-hand lane except when you are passing, and then pass on the left. Never weave in and out of traffic, never pass on a curve or at an intersection or near the crest of a hill. And be careful how you trust the invitation of another driver to pass him on a curve or in any other dangerous position. If you have an accident, the responsibility will be yours, not his. Be wary also of the drunken or "wild" driver. Be careful how you pass him, and give him a wide berth.



This diagram will show you how to make right and left turns. Some cities prefer that cars turning left should keep straight ahead until after the center of the intersection is passed.

Overtake a car before you turn into the left-hand lane to pass it, and give it a warning toot when you are still some feet behind it Signal your intention before you start to shift lanes, and look in the mirror and through the windows at the left. Make sure you have plenty of time, and then pass expeditiously. Do not turn back into the right-hand lane until the car you are passing is well behind you. Observe white lines, marking off traffic lanes, and do not pass when the white line forbids it.

Do not drive too slowly on a crowded highway. A car that all other drivers want to pass is a menace on the road. In some states a man can be arrested for driving too slowly. If there are cars behind you, do not slow down when a car is passing unless it is absolutely necessary. If you do, you will hold back the whole stream of cars behind you, and may cause an accident. When traffic is light it is of course courteous to slow down to let another driver go by.



The car on the left is on the other side of the hill shown in the picture on the right. Its driver has no notion of what lies ahead of him. Is he driving too fast? If he is, there will be a terrible accident.

Never be so churlish as to refuse to let him pass.

After you yourself decide to pass—or to follow any other plan on the road—act with decision. Do not change your mind unless conditions suddenly change; and once you have started, do not waver. Give your signals clearly and then live up to them. Indecision is exceedingly dangerous on the road. The person to whom it is habitual may do well never to take the wheel of a car.

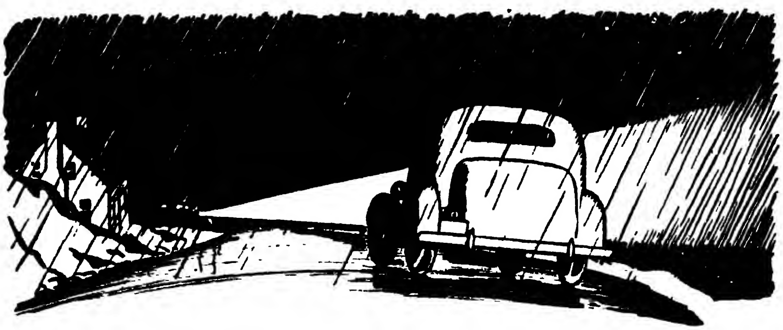
Keep Your Eye on the Road

No matter what or where you are driving, keep your eye on the road and both hands on the wheel. Do not allow your attention to be distracted either by talk inside the car or by events outside. If you must read a sign or find a house number, stop the car or have someone beside you get the information. Things can happen very rapidly, and sometimes only an instant's inattention can bring grave results. Animals and people can dart into the road from the side, or obstacles can loom up on the road itself. Besides, it is a psychological fact that one always tends to steer toward the spot one is looking at. Go very slowly and carefully wherever you are likely to find children in the road. Take great care in passing a school, or a church from which people are coming. This is a good time to put your car into second gear. It is important, also, to put it into second if you have to slow down for a railway crossing—as you always should do if you have to look out for signals. Take the greatest precaution, and then cross in second gear. A great many fatal accidents occur because motors stall on the track before an oncoming train that the driver has not heard. If you are driving in light traffic and have cars parked on your right, it is well to drive toward the center of the road. Numerous deaths are caused by pedestrians who step suddenly into the road from a row of parked cars. Watch, too, for people getting out of parked cars on the side toward traffic.

How to Park

There are a number of things to remember in parking. When you are drawing up parallel with the curb, leave three feet between your car and the ones at either end of it, and draw your car to within six inches of the curb. If you must park on an open road, draw well to the side, and do not leave your car all night without seeing that it has a red light to warn other drivers of its presence. Always leave your parking lights on when you park after dark. When you park on a hillside put on the handbrake, leave your car in reverse gear if you are facing downhill, and turn your front wheels into the curb—if there is a curb—so that should the brake give way, the curb will still hold the car. If there is no curb a good-sized stone can be wedged under the front wheel. If the car is facing uphill, leave it in low gear and turn the front wheels so that the back of the right-hand wheel rests against the curb—or wedge a stone behind one of the rear wheels. When you close a car door always look to see that no one's fingers are going to be caught.

Never move out of your parking place



Can you figure out the number of adverse conditions the car in the foreground is operating under? As a matter of fact there are at least ten—a down grade, a curve ahead, a crowned road, a wet surface, darkness, low visibility by reason of the rain, a blind entrance on the left, a car about to enter from the left, glare from its headlights, a car coming behind. What do you think would be a safe speed for the car in the foreground? You will have to assume that the car and its driver are in perfect condition!

without looking carefully to be sure that no car is coming, and giving a signal of your intentions. No matter where you are, always back with the greatest care, remembering that there is a "blind spot" at the back of your car -- that is, a spot that cannot be seen from the driver's seat. This is a fact that pedestrians should always remember when they stand behind a parked car. Of course backing at night is doubly dangerous—and no one but an experienced driver should ever try to back downhill. Remember, in backing out of a garage, that you do not have the right of way. It belongs to the pedestrians on the sidewalk and to cars passing on the street. If the traffic is dense, wait your opportunity, and then enter with the greatest care.

What Is the "Right of Way"?

The "right of way" is a shadowy thing at best—not really a "right" at all, but a privilege that other occupants of the road grant you in order that traffic may move smoothly. It is a code of courtesy, if you like—a thing no one should ever insist upon. For what is the comfort of knowing that you had the right of way if you are crippled in battling for it? It belongs to all pedestrians, except when lights or signals are against them. It always belongs to an ambulance, fire truck, or other conveyance carrying a siren. When you hear a siren, draw at once to the side of the street or road and allow the vehicle to pass. And in all the hundred and one situations that arise on the road, do not insist upon having the right of way. Fall back, rather, on rules of sportsmanship and courtesy. They will stand you in much better stead. For *lack of courtesy is responsible for half the accidents on our highways.*

The Doctrine of "the Last Clear Chance"

The law recognizes all this in the doctrine of "the last clear chance." According to this doctrine a judge will place responsibility for an accident on the last man who was in a position to prevent it. He may not have been the first one to make the mistake, but he was the one who finally caused the accident. In other words, since all of us make mistakes at times, it is our duty to protect other people, both drivers and pedestrians, from the consequences of their own errors.

Now a great many accidents are the fault of pedestrians. People on foot are careless; they are reckless; they are aged, blind, deaf, or confused; the older ones go into crowded motor traffic as if they were making their way among the horses and buggies on the village street they knew when they were young. People cross on red lights, they cross diagonally at intersections, they step out suddenly from behind parked cars, and they cross in the middle of a block—a practice that is five times as dangerous as crossing at the intersection. One of the worst things they do is to start across a street in pairs or trios and then scatter in all directions when a car approaches. A driver has no room to make his way between them, and cannot avoid running one of them down. In other words, pedestrians are very badly in

need of education. They are the victims of 40 percent of the fatal traffic accidents.

Kansas City's Fine Record

It is encouraging to know that they are being educated in many ways, and with very gratifying results. In seven years Evanston, Illinois, reduced its traffic deaths from 24 per 100,000 to 2.9 per 100,000. In 1922 national child-safety education was begun, and now thousands of schools give safety instruction. As a result the fatal traffic accidents among children between the ages of five and fourteen have fallen 6 percent, while during the same time the rate for all ages has increased 112 percent. Lately Kansas City went well over a year without a single child's meeting its death in traffic. Children often shame adults by their refusal to cross highways against the lights or at the center of a block. The School Boy Patrol, helped on by the American Automobile Association, undoubtedly saved many young people from death in crowded traffic. Other organizations are helping to do away with other accidents. The Boy Scouts have done a great deal in teaching swimming and proper methods of making fires, and the Red Cross too teaches swimming. As the knowledge of this magnificent sport is spread, there surely will be fewer deaths from drowning. In 1935 they reached an appalling total of over 7,000.

Accidents among High-school Students

Unhappily during the period since 1922 the accident rate for young people of high school age increased 130 percent. Apparently it is to them that the gospel of good habits most needs to be taught. They have not learned to carry on their sports safely. They need to learn never to step into the street without first looking in both directions, never to dash in front of a car or behind it, never to coast or roller skate or play games in a street where traffic is passing, never to hitch to an automobile or ride on the running board or gesticulate out of a car window, never to bicycle in crowded streets, and to be doubly careful in crossing a street when they are carrying an umbrella. Many of them do not realize that a bicycle should keep close to the curb, should carry a lamp and horn, and should obey traffic regulations just as an automobile does. Bicycles are growing more and more popular, and should be handled with a great deal more care than is used at present.

As we have said, education is also coming to the rescue of the man behind the wheel. Every community has its legend of the hardy lawyer or doctor who got the first car in town and rode round and round the block "at the terrific speed of eleven miles an hour," calling meanwhile for someone to jump on and stop the thing. That was in 1900. To-day the age of such experimentation is past. The new driver knows he does not need to "muddle through," learning by sad experience. There are automobile schools to teach him, and a good many tests to find out his natural aptitude.

High-school Courses in Driving

And best of all is the fact that high schools are teaching driving as a regular course. The American Automobile Association is sponsoring a national program in this field—"Sportsmanlike Driving," it is called—and other groups are attempting it in various localities. Training-cars with double controls are being used, and students go out for road work in groups of four with a teacher. The three on the back seat learn a great deal by watching the one whose turn it is to take the wheel. Boys and girls in this way become skillful drivers at the start, and learn at an age when learning is easiest.

Of course there must be teachers of unusual personality and varied abilities to carry on this work. And that too is part of the program—teachers are trained to teach driving. It has become a separate field in the teaching profession. The first course of this kind was conducted at the Pennsylvania State College in the summer of 1936. Since then other colleges have included the subject in the curriculum. It is a splendid and very necessary work. Perhaps in another ten years, when well informed, well trained, responsible, considerate drivers have displaced the incompetent ones, we shall see the record of traffic accidents reduced to its proper proportions.

And safety has to do not only with people

but also with things or property, for that too must be protected, chiefly from loss by fire. We must use special care in handling matches, gasoline, and oil. Great precaution is needed in storing rubbish and in setting bonfires, either in the city or the country. And one should never leave a bonfire or campfire until the last embers have been put out.

Take Care on the Fourth of July

Precaution against fire is especially necessary around the Fourth of July, since that date brings out a blaze of fireworks dangerous to life as well as to property. Fireworks have come to be such a hazard that the manufacture and sale of them is now regulated in most cities and states. Laws have also been passed in many states to regulate the ownership, carrying, and use of firearms, since guns and pistols, and even toy cap pistols, still play a large part in swelling the accident record. A great many other tragedies occur during the hunting season.

Christmas too demands safety precautions, for then there is added danger of accidents from electrical apparatus and of fires from lighted Christmas trees and other holiday decorations. The skating season calls for precaution against falling and against the danger that lurks under thin ice; and summer with its camp life, hikes, and water sports demands alertness and level-headedness from those who would get through the season safely and would help others do the same. There is always need of care if one is to have a safer and longer, a happier and more interesting life.

For though it is true that danger of accident is all about us, it also is true that with all the advantages now lying ready to hand, life is more interesting than ever before if we will only use our eyes and ears and common sense to discover where danger lurks. No one need go through this fascinating world and be a slave to fear. Having found what is dangerous, we shall be cautious and alert enough to avoid it. Boys and girls on the farm will discover their especial problems, and so will children in the city. Each should learn to solve his own.

In both country and city, machinery and construction work present many hazards, especially to children. That is because of youthful curiosity and interest in "things that work." Mines, quarries, rock piles, and excavations are fascinating places for play, as are also huge pieces of machinery, scaffolds, and all sorts of building work. But they are all the more to be avoided on that very account, for accidents at such places usually involve long falls or the dislodging of heavy materials. Children can best practice safety first by avoiding such places, which are dangerous enough for the practiced workmen who labor there.

The Great Intelligence Test

So play where it is safe and play with a will. Banish fear by recognizing the danger and meeting it wisely. And since at last America has awakened to the idea of conserving human life do all in your power to help the movement along. Join in the safety work your school and community are carrying on through the Junior Safety Scouts, the National Safety Council, and Safety Week. To be "safety-minded" is a kind of intelligence test. Make it your duty to spread this life-saving knowledge. You may be sure that in doing so you are saving human lives.